Science is defined as any systematic and empirical activity that enhances the physical world knowledge, which produces the same result under different conditions. Technology can be defined as that activity which makes a productive use of this knowledge.

1.1 SCIENCE IN EVERYDAY LIFE

In the current world, science and technology plays a significant role in our daily life, affecting every single moment of our life. It makes citizens better informed as well as capable enough to adapt to the many changes that science and technology have brought, and will continue to bring, to their lives. Science and technology (S and T) have achieved various advancements in medicine, communication and transportation; thus making our everyday life vastly different from that of earlier generations.

Our understanding of electricity is built by science. Science helps us in communicating through telephone lines, entertains us through our televisions and also helps us in keeping the lights on. Science brings a great transformation in our eating habits. High-yielding varieties of corn, wheat and rice began to develop in 1940s, which dramatically increased the yield when paired with new fertilisers and pesticides, paving way for the Green Revolution. Such science-based technologies resulted in striking changes in agriculture, massively increasing the amount of food available to feed the world while simultaneously transforming the economic structure of agricultural practices.

In 1700s, **Edward Jenner explained the working of vaccination, firstly against small pox.** In the 1800s, scientists and doctors established the theory of germs causing diseases. **Alexander Fleming discovered the first antibiotic, penicillin, in 1920s.** The impact of modern medicine has been proven in various areas, such as eradication of smallpox, preventing nutritional deficiencies and successful treatments of infections against deadly diseases.

Scientific knowledge can improve the quality of life at many different levels – from the routine workings of our everyday lives to global issues. Science informs public policy and personal decisions on energy, health, transportation, communication, defence, conservation, agriculture, economics, leisure and exploration. It is almost impossible to list the many aspects of modern life that are impacted by scientific knowledge.

1.2 HOW IS SCIENCE AND TECHNOLOGY AFFECTING HUMAN LIFE?

Science is a base of methodical knowledge, which includes a chain of steps to get the possible outcome. Science is generally related to theories and it also gives special focus on analysis and brings many advantages to mankind, while technology is concerned with the applied science and includes processes, wherein the study of a particular science is undertaken with the help of tools and knowledge.

Advantages

- Science and technology makes human **life simpler** through various innovations in every sector.
- With the invention of **Artificial Intelligence**, people are making **lesser mistakes**. The use of technology has many benefits, it **saves time** and effort and also provides **quality outcomes and life with high production.**
- In medical science, technology brought a revolution through **discovery of various medical or surgical equipments, medicines and procedures** which are helping in **extending the life span of human beings** and saving many lives.
- Science and technology also make life easy to bring a **revolution in communication** system. Communicating through telephones, cellular phones and emails with the help of computers and the internet brought a revolution in communication system. Satellites-based communication system is also very useful for human beings.
- The events broadcast across the globe have eased with the help of **TVs and satellite radios.**
- The **software industry, being one of the world's most progressive industries, has evolved as a result of computers.** Everyone, including the teenagers, is using these latest gadgets to stay entertained.

Disadvantages

With such advancements in the field of latest technology, it also brings out many disadvantages.

- It negatively **affects the environment.** The **advanced transportation** results in air pollution.

- With the adoption of automatic machineries in the factories for improving production with accuracy, **people are losing their jobs.**
- These **machines may seem inexpensive** and good to use but **require lots of maintenances, which ultimately make them expensive.**
- Our healthiness is also being affected by technology, thereby **causing eye disease, enhanced body weight and cancer due to specific radiation technology.**
- People are becoming lazy and dependent due to technology.
- Now-a-days, children prefer to play computer games in place of outdoor games, which are not good for their physical growth.
- People are also **facing privacy issues like email hacking, cell phone signals interceptions,** etc.
- There is a huge increase in the number of **cyber-crimes, fraud** and **cheating cases** due to the advancement of technology.
- Above all, due to the latest technology, there is **increase in the issues of internal security and terrorist threats.**
- If the usage of these advancement and inventions takes place in a right way, we can benefit from them. On the other hand, human beings will face the disadvantages due to technology, if their intentions are not positive.

1.3 INDIGENISATION OF TECHNOLOGY AND DEVELOPING NEW TECHNOLOGY

Indigenisation is an action or process to bring anything under the control, dominance or influence of the people those are native to an area. It is a substitution of imported products which are manufactured within the country.

'Make in India' scheme was launched in 2014, to improve India's manufacturing. This scheme was to support the indigenisation of technologies in various sectors like electronics, ICT, defence, space, transport, etc.

It leads to the utilisation of its own resources by the nation to develop itself. Due to use of own natural resources, it will be cheaper and easy to harness. It is not only a technological advancement, but also a huge morale booster for any nation. Science has always made work so easier and even more efficient over the period of time.

Advantages of Indigenisation of Technology

There are various advantages of indigenisation of technology:

- Firstly, it has a huge impact on psychological and socioeconomical development.
- It will open a new vista for various jobs in manufacturing and other sectors.
- It will make the product very cost effective, and much cheaper for the same quality of product that we import from other nations.
- It will improve scope of research and development sector in India. Hence, India will lead more projects in the name of innovation.

Limitations of Indigenisation of Technologies

- Indigenous technology may be cheaper but inferior to other technologies, available in the global market.
- Indigenous technology may lead to higher wastage and increase production costs which will reduce the demand for a product.
- Since indigenous technology is tested in only one country, there are chances that it may not work if environment or other factors change.

Development of New Technologies

Since its independence, India has been working immensely towards becoming a self-sustained nation and has integrated indigenisation of technology in various sectors of economy which was completed in five phases to strengthen science and technological advancements.

Phase I: It was focused towards building of relevant infrastructure.

Phase II: It included reorientation of various facilities.

Phase III: It promoted the indigenous technology.

Phase IV: It involved in moving towards the economic liberalization.

Phase V: It involved development of science and technology towards becoming an economically liberalised nation.

There are six main sectors which promotes indigenisation and development of new technology in India:

Agriculture: it always has a major share in our GDP.
Automobile: it is a leading employment provider in India.
Defence: the prime sector for maintaining security of India.
Information and Communication Technology: fastest growing and the most needed sector in India.
Healthcare and biotechnology: an emerging field and the future of science and technology.
Space: symbolic significance in the field of science and technology.

1.4 DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN ANCIENT INDIA

- A good knowledge of measurement and geometry is showed in the town planning of Harappa. The **Shulba Sutras** is supposed to be the origination of Indian Mathematics.
- From the Indus Valley excavation points, bronze and copper artefacts, and glazed potteries were found, which shows their knowledge of highly modified metallurgy.
- There was awareness in the Vedic people regarding the fermenting of grains and fruits, tanning leather, as well as dyeing process.
- The first century A.D. also witnessed mass production of metals such as iron, copper, silver, gold and also alloys such as bronze and brass.
- Indian contribution to shipbuilding can be witnessed at Lothal, a site in Gujarat, which houses the remains of dockyard, further providing proofs of trade flourishing through sea in those days.
- **Varahamihira** was among the nine gems in the court of Vikramaditya. The king gave him the title of 'Varaha' because of his accurate predictions. His **Brihat-Samhita** is considered a pioneer work in the field of Astronomy. He observed that the moon revolves around the earth and similarly, the earth revolves around the sun.
- Baudhayan was the first person to calculate the value of pie; Pythagoras theorem is found in Budhayan's **Shulba Sutra.**
- The summary of Mathematics was mentioned in Aryabhatta's book, known as **Aryabhatiya.** He explained zero as a symbol as well as a concept, which helped him in understanding the accurate distance between the earth the moon. He also mentioned that **'Earth is round and rotates on its own axis'**. He also correctly stated that reflected sunlight is the reason behind the lustre of the moon and the planets.
- Brahmagupta introduced multiplication methods in which there is the usage of place value in the exact way as it is used these days. In his famous work, **Brahma Sputa Siddantika,** there is the introduction of negative numbers and operations on zero.
- Bhaskaracharya is renowned for his book **Siddanta Shiromani,** which has four sections: **Beejaganit (Algebra), Lilavati (Arithmetic), Giahaganit (Planets Mathematics) and Goladhyaya (Sphere).** He had also introduced a method to solve algebraic equations called as Chakrawat Method or the Cyclic Method.
- The first arithmetic textbook, is **Ganit Sara Sangraha,** which was written by Mahaviracharya in 850 A.D.
- Kanad, a sixth-century scientist, propounded atomic theory, which is very much similar to the present-day theory of atom. As per the theory, material world, which is formed of *kanas,* is invisible and indestructible.
- Varahamihira played an important role in the fields of Geology, Hydrology and Ecology. He had also stated that the presence of termites and plants could very well be the indicators of the presence of underground water. In his book, **Brihat Samhita**, he tried to correlate the natural process like undersea activities, planetary motions and unusual cloud formation, which are believed to be the causes of earthquake.
- Ayurveda is the oldest branch of medical science, which was developed in ancient times. The oldest known medical book of the world is **Atreya Samhita.**
- **Charak is known as the Father of Susruta and Ayurvedic medicine** and is also known as the **Father of Surgery.** In Atharva Veda, for the first time, diseases, their cure and medicines were mentioned for fever, cough, consumption, diarrhoea, dropsy, sores, leprosy, etc.
- In India, there were emergence of medicine and learning centres at places such as Takshila and Varanasi.

- **Charaksamhita** by Charak and **Sushrutsamhita** by Sushruta are the two vital texts in this field. In the court of Kanishka, Charak was the Raj Vaidya (royal doctor). He is credited as the first person who talked about digestion, metabolism and immunity. He also knew the concepts of Genetics. He greatly contributed in Rhinoplasty (plastic surgery) as well as in ophthalmic surgery (removal of cataracts). Surprisingly, modern surgeons use techniques similar to that of Sushruta during plastic surgeries.
- Yoga originated during ancient time as an allied Ayurveda science, for curing the body at the physical and mental level without any medicine. The Sanskrit word **Yoktra (yoking of the mind to the inner self after detaching it from the outer subjects of senses)** is used for the derivation of the term **Yoga**. Hathyoga is physical and mental yoga, whereas Rajayoga is mental yoga. The purpose of yoga is the achievement of mental, physical, emotional and spiritual balance through bondage liberation and self-realisation. Patanjali is the person behind this great science. In his book *Yoga Sutras*, he mentioned **'Aum'** as a cosmic sound, spoken of as the symbol of God. Among his other works, Patanjali is known for his book on medicine and his work on Panini's grammar, known as **Mahabhasaya.**

1.5 DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN MEDIEVAL INDIA

- In the medieval period (eleventh to eighteenth centuries), India's science and technology was influenced by dual scenarios: First, by the earlier ancient tradition and second, by Islamic and European traditions.
- People were invited from Arabia, Persia and also from Central Asia to **teach in the *madarsas.*** Arithmetic, Mensuration, Geometry, Public Administration, Astronomy, Accountancy and Agriculture were some subjects included in primary education. Although numerous efforts were made by the rulers of that time to reform the education system, science did not make much development.
- Akbar was focussed on producing different domestic animal breeds, including elephants and horses. The **Tuzuk-i-Jahangiri** is Jahangir's book having weeding and hybridisation records of his experiments and observation.
- **Lilavati Kammdipika, Suddhantadipika and Lilavati Vyakhya** are the books written by Gangadhar in which he confers trigonometric terms such as sine, cosine, tangent and cotangent and their rules.
- Akbar made Mathematics as a study subject during his regime.
- During the early medieval period, there were two outstanding works in Mathematics, one was **Ganitasara** by Sridhara which was about numbers, multiplication, cubes, division, square roots, mensuration among others, and **Lilavati** written by Bhaskara.
- During Tipu Sultan's regime, a paper-making factory was established in Mysore, that produced a gold-surfaced paper. The Mughals were familiar with the technique of producing gunpowder with the use of sulphur, saltpetre and charcoal in variable ratios for its usage in different guns. The casting of cannons was mentioned in **Tuzuk-i-Baburi.**
- **Ain-i-Akbari** gives a description of the 'Regulations of the Perfume Office of Akbar'. The attar of roses was among the most famous perfumes.
- An astronomical observation post was established by Firoz Shah Tughlaq. An astronomical instrument named as **Yantraja** was developed by Mehendra Suri, who was the court astronomer of Firoz Shah.
- Five astronomical observatories were developed by Sawai Jai Singh, the Maharaja of Jaipur, in five different cities, i.e., Delhi, Ujjain, Varanasi, Mathura and Jaipur.
- **Sarangdhara Samhita** recommended opium as a medicine.
- A new medicine system was introduced in India by Muslims during the eleventh century, i.e., Unani medicine system. Majinye Diyae by Hakim Diya Muhammad is a compilation of Arabic, Persian and Ayurvedic medical knowledge.
- The field of agriculture witnessed some important changes like introduction of trees, new crops and horticultural plants. The major crops during that time were wheat, rice, barley, millets, pulses,

oilseeds, sugarcane, indigo and cotton. New and improved horticultural methods were adopted.

1.6 DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN MODERN INDIA

1.6.1 First Phase (1947–1967)

Pt. Jawaharlal Nehru, the first Prime Minister of India, initiated various reforms to promote higher education in the field of science and technology in India. **The first IIT (Indian Institute of Technology) was established in 1951 at Kharagpur in West Bengal by Maulana Abul Kalam Azad.** Thereafter, many other IITs were shortly established at Bombay, Madras, Kanpur and Delhi during 1950s and 1960s.

Various achievements between 1947 and 1962 were food grain production rose through 34 million metric tonnes, installed capacity of power generation increased through 79 million kilowatts and an overall increase of industrial production to 94% during these periods. **Radio broadcasting in India was started in 1927. It was named 'All India Radio' in 1937.** Since 1957, it has been called '**Akashvani**'. The Tata Group established Tata Consultancy Services in 1968, which was among the largest software producers in the 1960s.

During 1960s, India's relation with Soviet Union helped the Indian Space Research Organisation (ISRO) to build up the Indian space programme and advanced nuclear programme. **Operation 'Smiling Buddha' is the name of the first nuclear test that was conducted on 18 May 1974 at Pokhran in Rajasthan.**

The Indian space programme strives for self-reliance in the usage of space technology in support of national development. **It includes the launching of the first Indian space satellite Aryabhatta in 1975,** followed by **Bhaskara I** and **Bhaskara II** with Soviet Union assistance, the **Apple satellite on the European Arianne rocket** and the **Rohini satellite on India's own SLV-3 rocket.** Subsequently, **INSAT I-B was launched in the year 1983,** which catered to television, radio, meteorological and telecommunication services. The **Council for Scientific and Industrial Research (CSIR)** and **Defence Research and Development Organisation (DRDO),** the two government organisations, are involved in an extensive range of research in the field of science and technology for both defence and civil purpose. India's space programme started with the Soviet Union's financial support, which assisted the Indian Space Research Organisation in the achievement of its aims such as the establishment of **Thumba Equatorial Rocket Launching Station** for remote sensing satellites launching, and also in development of Aryabhatta – India's first satellite, while also sending space astronauts.

1.6.2 Second Phase (1967–1987)

America supported India to begin first nuclear power generation in **Tarapur Atomic Power Station and Canada's CANDU reactors.** The **Green Revolution** was brought in India during 1960s, which led to the production of high-yield food varieties and use of chemical fertilisers in India. The farmers belonging to wheat-growing areas (Haryana, Punjab and western Uttar Pradesh) were most benefited. The application of modern science and technology supported the agriculture to flourish rapidly. The efforts of **Indian Council for Agricultural Research (ICAR)** have played a major role in the cultivation of high-yielding food crops and post-harvest technology. This made India self-dependent in maintaining the food buffer stock for the people.

1.6.3 Third Phase (1987 to Present)

In 1986, the **Department for Biotechnology** Research was established under the aegis of Ministry of Science and Technology. Both the Indian government and the private sector could invest in the field of Biotechnology for medical and agricultural applications. **Bangalore is known as the technological capital of India.** Hyderabad, Bangalore and Chennai are considered as the golden triangle of IT and technology, which constitute the vertebrae of R&D, Science and Technology and Indian Manufacturing. Under the Prime Minister's charge, in the year 1981, the Department of Ocean Development was established to harmonise and direct the country's activities in ocean research. It works in biological, chemical, physical and geological field besides Meteorology and Geophysical Oceanography.

India first entered the space mission with the successful launch of Chandrayaan-I on 22 October

2008. The Moon Impact probe from Chandrayaan-I was released on 18 November 2008, from a height of 100 kilometres. During its 25-minute descent, Chandra's Altitudinal Composition Explorer (CHACE) recorded evidence of water. **On 5 November 2013, the Indian Space Research Organisation (ISRO) launched a second space mission of India, i.e., Mars Orbiter Mission,** which is also known as Mangalyaan. It is the first interplanetary mission of India, making ISRO the fourth space agency to reach Mars after Soviet Space Programme, NASA and European Space Agency. India is the first Asian nation to reach the orbit of Mars and also the first nation to get the success in its first effort. India also launched Chandrayaan-II mission, on 22nd July 2019. **The Thirty Meter Telescope (TMT)** is an anticipated astronomical observatory having an extremely large telescope, which is to be constructed on the summit of Mauna Kea in the United States, near Hawaii, and further going to be planned for ultraviolet to mid-infrared observations (0.31 to 28 μm wavelengths). There is government support from several nations that spend on R&D, such as **Japan**, **United States**, **Canada**, **China** and **India** for the development of this telescope. This observatory and telescope are likely to be operational at **Mauna Kea till 2024**.

1.7 INDIAN SCIENTISTS AND THEIR CONTRIBUTIONS

1.7.1 Srinivasa Ramanujan Aiyangar (1887–1920)

- Srinivasa **Ramanujan** worked during the British Rule in India.
- He was an **Indian mathematician** and made substantial contributions to **mathematical analysis, number theory, infinite series and continued fractions,** including solutions to mathematical problems then considered unsolvable.
- Ramanujan has compiled nearly 3,900 results (mostly identities and equations), such as the Ramanujan prime, the Ramanujan theta function, partition formulae and mock theta functions, which opened entire new areas of work and inspired a vast amount of further research.
- He was one of **the first Indian to be elected a Fellow of Trinity College, Cambridge and the youngest Fellows of the Royal Society.**

1.7.2 Chandrasekhara V. Raman (1888–1970)

- He was the first Asian to be conferred with the Nobel Prize in Physics in the year 1930.
- Various experiments were conducted and also a research paper on molecular scattering of light was prepared by him.
- The debate on the nature of light, whether it is waves or particles, was ended by the **'Raman Effect'**, which proved that light is made up of particles known as photons.

1.7.3 Jagdish Chandra Bose (1858–1937)

- J.C. Bose was knighted for his paper in 1917 on 'The Electromagnetic Radiation and Polarisation of Electric Ray'.
- Dr. Bose invented **Crescograph**, which is used for the recording of even the millionth part of a millimetre of plant growth and its movement.
- He has demonstrated through cresograph that the sap's upward movement in plants is the living cells activity.

1.7.4 Homi Jahangir Bhabha (1909–1966)

- Bhabha is also known as the **Father of Indian Nuclear Science**.
- He suggested Sir Dorab Ji Tata for establishing an institution to lay the country's foundation as a world nuclear power, which led to the establishment of Tata Institute of Fundamental Research (TIFR).
- The country's first atomic research centre, which is Bhabha Atomic Research Centre (BARC), was set up at Trombay, under his expert guidance.
- **The country's first atomic reactor – Apsara –** was established during his period.
- He became the first chairman of Atomic Energy Commission, which was established in the year 1948.
- He was a recipient of Padma Bhushan by the Government of India. Homi Bhabha Prize is given for the special contribution in **'Theoretical Physics'.**

1.7.5 Vikram Ambalal Sarabhai (1919–1971)

- Under the expert guidance of Dr. Vikram Ambalal Sarabhai, **India launched its first satellite, Aryabhatta.**
- He established industries like Sarabhai Geigy Ltd., Sarabhai Glass, Sarabhai Chemicals, Sarabhai Merck Ltd. and many others.
- His efforts saved crores of Indian rupees by initiating the mission of antibiotics and penicillin production and military hardware manufacturing in India.
- The credit for establishing various reputed institutes in India goes to Dr. Vikram Ambalal Sarabhai.
- One such prominent example is Indian Institutes of Management (IIMs).
- Dr. Sarabhai also served as the chairman of the Indian National Commission for Space Research (INCOSPAR) and the Atomic Energy Commission.
- He was the director during the establishment of the Thumba Equatorial Rocket Launching Station (TERLS).
- Sarabhai was conferred with the Padma Bhushan and the Padma Vibhushan.
- He had also taken initiatives for spreading education with the help of satellite communication to the villages.

1.7.6 A.P.J. Abdul Kalam (1931–2015)

- **Dr. A.P.J. Abdul Kalam** was born on 15 October 1931 in the island town of Rameshwaram in Tamil Nadu.
- He was the eleventh President of India.
- He was honoured with the highest civilian award of India, Bharat Ratna, in the year 1997 for his contributions in the science and engineering field.
- Dr. Kalam had served in Indian Space Research Organisation from the year 1963 to 1982. Dr. Kalam developed the **Satellite Launch Vehicle (SLV 3)** at Vikram Sarabhai Space Centre, which placed the satellite Rohini into orbit.
- During his tenure as the Director of Defence Research Development Organisation (DRDO), he was entrusted with the responsibility of **Integrated Guided Missile Development Programme (IGMDP)** and subsequently he developed five defence services projects, namely, Prithvi, Trishul, Akash, Nag and Agni.

In his life, **A.P.J. Kalam has written many books:** *Target 3 Billion, Developments in Fluid Mechanics and Space Technology, India 2020: A vision for the New Millennium, Envisioning an Empowered Nation, A Manifesto for Change: A Sequel to India, You Are Born to Blossom, Reignited: Scientific Pathways to a Brighter Future, Transcendence: My Spiritual Experiences with Pramukh Swamiji, My Journey: Transforming Dreams into Actions, Indomitable Spirit, Ignited Minds: Unleashing the Power Within India, The Luminous Sparks, Mission India, Inspiring Thoughts, Forget Your Future: Candid, Forthright, Inspiring, Turning Points: A Journey Through Challenges.*

1.7.7 Krishnaswamy Kasturirangan (Born in October 1940)

- He headed ISRO from 1994 to 2003. Earlier, he also served as the Director of ISRO Satellite Centre and under his supervision, new generation spacecraft – the Indian National Satellite (INSAT-2) and the Indian Remote Sensing Satellites (IRS-1A and 1B), besides several scientific satellites, were developed.
- He served as the **Project Director for India's first two experimental earth observation satellites, Bhaskara-I and II.**
- He also led the country's initiative for entering into an era of the planetary exploration through extensive studies which led to the conceptualisation of Chandrayaan-I.
- He was honoured with the Padma Shri (1982), Padma Bhushan (1992) and Padma Vibhushan (2000).

1.7.8 Raghunath Anant Mashelkar (Born in January 1943)

- He is also known by his other name Ramesh Mashelkar. He served as the Director General of the Council of Scientific and Industrial Research (CSIR).
- After independence, he played a significant role in shaping India's policies of science and technology. He served as a member of the Scientific Advisory Council to the Prime Minister while also leading the successive governments.

- Under the chairmanship of Mashelkar, a technical expert group on **patent laws was established in 2005**, so as to find out whether the amendments made in Indian patent law were TRIPS compliant or not. The committee concluded unanimously that the amendments were not TRIPS compliant.
- He was awarded the Padma Vibhushan in 2014.

1.7.9 Tessy Thomas (Born in April 1963)

- Tessy Thomas headed the programme on the Agni-IV missile of Defence Research and Development Organisation (DRDO), which was successfully tested in 2011. Thomas is also recognised as **India's 'Missile Woman' (Agni Putri).**
- In 2009, the Advanced Systems Laboratory in Hyderabad appointed her as the Project Director for 5,000 km range Agni-IV.
- Her outstanding contribution in the field of missile technology for making India self-reliant has made her win the Lal Bahadur Shastri National Award.

1.7.10 Udupi Ramachandra Rao (1932–2017)

- U.R. Rao was the former chairman of Indian Space Research Organisation.
- He was conferred with the Padma Bhushan in 1976.
- He made a great contribution for the establishment of Indian satellite technology in 1972.
- Under his supervision, many satellites were designed and launched with an aim to provide communication, remote sensing and meteorological services. These include India's first satellite '**Aryabhatta**' in 1975, Bhaskara, APPLE, Rohini, INSAT-1 and INSAT-2 series of multipurpose satellites and the IRS-1A and IRS-1B remote sensing satellites.

1.7.11 Venkatraman Ramakrishnan (Born in April 1952)

- He is an Indian-American and British structural biologist of Indian origin.
- He won the Nobel Prize in 2009 in Chemistry, **'for studies of the structure and function of the ribosome'.**

1.7.12 Verghese Kurien (1921–2012)

- Verghese Kurien is **Father of the White Revolution** in India.
- He is the person behind **Operation Flood**, which was the largest agricultural dairy development programme in the world and India is the top ranked milk producer in the world.
- **India's largest food brand Amul Cooperative was established with his help.**
- He also made India self-sufficient in the production of edible oil, taking on a powerful, entrenched and violently resistant oil supplying lobby.
- He is one of the greatest supporters of the **cooperative movement** in the world.
- His work helped in the upliftment of millions of people out of poverty in India as well as outside.

1.7.13 Satyendra Nath Bose (1894–1974)

- He was an Indian physicist and mathematician, who is best known for his work with Albert Einstein on the **'Bose–Einstein Statistics'** that has application in information retrieval in present time.
- He worked on boson also called God particles, which revolutionised the modern Physics.
- The name Boson was given after his name and Bose is known as the **'Father of God Particle'.**

1.7.14 Subrahmanyan Chandrasekhar (1910–1995)

- He was an astrophysicist. He discovered and concluded that massive stars can collapse under their own gravity to reach enormous or even infinite densities. Now, these collapsed stars are referred as **neutron stars** and **black holes.**
- Small and dense stars go on to become white dwarfs while larger stars, after a supernova, can become neutron stars or black holes.
- He was awarded with the Noble prize in Physics in 1983 for 'theoretical studies of the physical process of importance to the structure and evolution of stars', sharing the prize with William Fowler.
- NASA's **Chandra X-ray observatory** is named after him.

1.7.15 Har Gobind Khorana (1922–2011)

- **Har Gobind Khorana** was an **Indo-American biochemist.**
- He received **Physiology** or **Medicine Nobel Prize in 1968** with two other colleagues for the study of nucleotides in nucleic acids, and analyse genetic code of the cell those are responsible for the control of protein synthesis.
- Khorana also received the **Louisa Gross Horwitz Prize** from Columbia University in the same year, with Nirenberg.
- Khorana served as faculties of three universities in North America.
- He also received the **National Medal of Science in 1987.**

1.7.16 M. Visvesvaraya (1861–1962)

- He was an **Indian civil engineer and statesman** and the 19th Diwan of Mysore, who served from 1912 to 1919.
- He received India's highest honour, **Bharat Ratna, in 1955.**
- He was knighted as a **Knight Commander of the British Indian Empire (KCIE)** by King George V for his contributions to public good.
- **India, Sri Lanka and Tanzania** are celebrating **15 September as Engineer's Day in his memory.**
- He was **Chief Engineer to work for flood protection system for city of Hyderabad** and also involved in the **construction of Krishna Raja Sagara dam** in North-West suburb of Mysore.

1.7.17 Raja Ramanna (1925–2004)

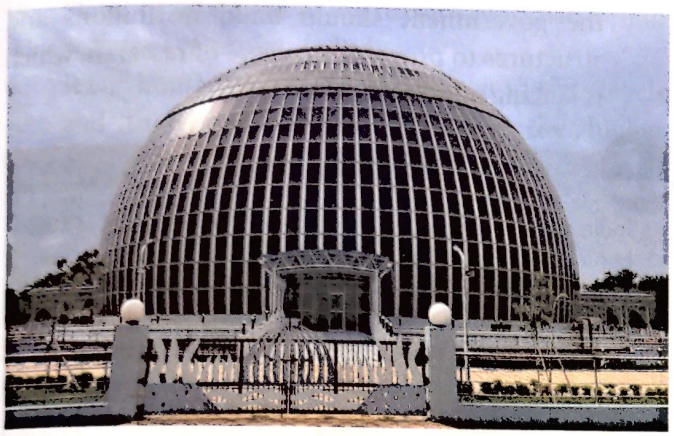
- **Raja Ramanna** was an **Indian physicist** and has played a very important role in earlier stages of **India's nuclear programme.**
- In the beginning Ramana had worked under Homi Jehangir Bhabha, and later became the director of this programme in 1967.
- Ramanna had **expanded and supervised many scientific research on nuclear weapons.** He was the first directing officer of the small team of scientists who **supervised and carried out the test of the nuclear device,** under the codename ***Smiling Buddha,*** **in 1974.**
- Ramanna was associated **for more than four decades with India's nuclear programme and also directed it.** He also initiated industrial defence programmes for the Indian Armed Forces.
- He received **Padma Vibhushan,** in the honour of his services to **build India's nuclear programme.**

1.8 RATIONAL USE OF SCIENCE AND TECHNOLOGY: KEY TO DEVELOPMENT OF RURAL INDIA

Around 70% of the country's population lives in rural areas. Thus, the development of rural India shall reflect the development of the whole country. For this to happen, an intensive focus on the conservation of natural resources and the use of sustainable technologies will have to become a prerequisite. In our villages, millions still cook using fossil fuels in earthenware. Their exposure to smoke causes serious health hazards. The present government has launched a new initiative to provide LPG connections to poor people. The users who can afford LPG at market price may give up subsidy on their gas connections and help providing clean fuel to a BPL family.

Dr. Harsh Vardhan, the then Union Minister for Science and Technology, launched an equipment in April 2016 called **'Solar Dome'**. The device will help illuminate people's houses in rural areas where electricity has not reached. The photovoltaic cells in this device store sunlight and can provide light for 8 to 10 hours. Such innovative methods of alternative/ renewable energy will also help the people to do their routine work during night hours. This will also prove to be a boon to school-going children who are forced to study under the dim light of candle or lantern. **Recently, the first solar dome was opened for public viewing in Bengal's Silicon Valley, Eco Park, New Town, Kolkata.** The dome is 28.950 metre high and has a 45-metre diameter. It has 2000 active solar panels which continuously generate solar power. Further construction is still on and after the project is complete, it will provide 180 kilowatts of energy which will light the internal facility as well as the street lights in the area.

A number of new and innovative techniques have been developed in the field of construction. Low cost and environment-friendly building materials and designs are being used. Structural Engineering Research Centre (SERC) located in Chennai and



First solar dome in Bengal's Silicon Valley

Central Building Research Institute (CBRI) in Roorkee are premier research institutions under CSIR umbrella, doing commendable R&D work in the field of building technology. CBRI has developed '**Fluorogypsum Plaster**' that is imperishable in the rain and can sustain for long. Portable C-brick machine is such a low-cost technology, which uses fly ash, sand and cement for the building of durable and good quality bricks. This can substantially reduce the cost of construction and go a long way in meeting demand of pucca houses, especially in rural areas. In addition, these institutions have contributed in the development of sustainable and efficient building technologies, such as earthquake-resistant structures, use of rice husk in making wood, etc. Such sustainable and low-cost technologies are not only in the interest of rural population but affordable to them also. Health of rural public plays a crucial role in rural development. Primary Health Centres (PHC) and Community Health Centres (CHC) have been established with the aim to address several health issues of rural areas. Unfortunately, these centres are facing shortage of doctors and pharmacists/nurses. Modern medical technologies and their specialists are also lacking there. Due to lack of medical facilities, most of the rural population have to take recourse to nearby city hospitals. If PHCs and CHCs are well equipped with essential and modern medical technologies and facilities, health care in rural India could be better.

Science and technology have contributed significantly in promoting agriculture in our country over the decades. **Agriculture Information System (AIS)** plays an important and key role in ensuring the reach of agriculture-related information to farmers. Through different Information Processing Tools monitoring, we are able to know the situation of natural resources and environmental impact such as analysis of environment deterioration, soil erosion, deforestation, etc.

Since the last few years, **DD Kisan Channel** is providing dedicated programmes on agriculture. Facebook, Twitter and WhatsApp have caused wider promotion of this channel among urban and rural India. Content of the channel and its presentation are also innovative. Therefore, this channel is gaining popularity. Vigyan Prasar, which is an autonomous body of the Department of Science and Technology, Government of India, is engaged in public outreach for S and T communication. In rural areas, this body organises street plays, puppet shows and science exhibitions.

Also S and T is playing a great role in promoting education. Online education system has become a boon for those students who cannot attend school on a regular basis. Indira Gandhi National Open University (IGNOU) and Uttar Pradesh Rajarshi Tandon Open University (UPRTOU) are providing online education to undergraduate and postgraduate courses to both urban and rural students through online information technologies. National Institute of Open Schooling (NIOS) is a national organisation under the Ministry of Human Resource Development. It provides online education to students up to Class XII. Students of country's rural and remote areas are the targets for NIOS. Different vocational and life skill-related educational programmes have also been introduced at various centres of NIOS.

The National Informatics Centre (NIC) was established by the Department of Electronics in 1975. NIC is based on the nation-wide satellite communication network. It has developed District Information System (DISNIC) in each district of the country. A large number of training and information transfer programmes have been taking place through this system. This helps in making available valuable information for district and rural development.

1.9 LACUNAS IN SCIENCE AND TECHNOLOGY RESEARCH IN INDIA

We have evolved from environmental determinism (forces of nature were strong) to possibilism (nature gets humanised) with the support of our technological innovations. Technology, though having many

disadvantages, if highly used, has the potential to solve human sufferings. Through quality research, we unleash the hidden potential of our nature, which is profound.

Unfortunately, Indian government does not give due importance for strengthening the research potential of our country. Though there are a number of causes for such lackadaisical attitude towards research, the following are some of the major reasons.

- Most Indian universities look at research with a negative attitude. They neither inspire students to conduct quality research nor provide the independence, moral and financial support for bringing out good quality research.
- India has an average rank when it comes to government expenditure on research. Even after repeated demands from research for allocating more funds towards research for over a decade, only around 0.8% of GDP is spent on research. R&D expenditure per capita is also poor.
- Concentration of available financial resources and research opportunities among the premier institutes of the country and not letting regional level institutes affect quality of research, induces unnecessary stress among students (as too many students compete for limited number of available seats). Too many researchers in state universities are neglected.
- Misgovernance: Poor leadership quality, political intervention in allocation of funds for research and in deciding research proposal, which will be eligible for funding, presence of bureaucrats and the absence of professionals and scientists in the research proposal selection process are some of the major government-related impediments.
- Corporates are more enthused about research than government. They are more interested in developing technology, which will give them immediate financial return. They do not encourage fundamental research in science. This is one of the major reasons for lack of scientific temper among Indian students because they do not get any immediate economic return by pursuing core scientific research.
- Lack of research culture: On a more fundamental level, a pedagogical change is imperative to encourage scientific enquiry amongst the youth. With funding facility and flexibility, the government should build institutions and structures to promote a culture of research, which is lacking at present.

R&D FACTUAL DATA

India spends approx. 0.7% of its GDP on R&D, but is still behind many developing and developed nations. Brazil, Russia, China and South Africa spend around 1.2%, 1.1%, above 2% and 0.8%, respectively. The world average is around 1.8%. The developed countries such as the United States, Sweden and Switzerland spend about 2.9%, 3.2% and 3.4%, respectively. Israel spends 4.5% of its GDP on R&D, the highest in the world.

The share of Central government's spending on R&D is nearly 45.1% of total expenditure, while others like private sector industries having contributed about 38.1%, followed by state governments, i.e., up to 7.4%.

There is hardly any increase in participation of women in R&D, in spite of so many provisions and schemes announced for them.

Although the share of India in global research is low, it is trending positively year after year. And the number of researchers in the recent decade had also gone up.

1.10 BRAIN GAIN: INDIAN SCIENTISTS RETURNING TO INDIA

According to the Department of Science and Technology, the number of Indian scientists working internationally and returning to India showed a 70% jump between 2012 and 2017.

1.10.1 Reasons for Brain Gain

- This has been primarily due to schemes such as Ramanujan Fellowship Scheme, Innovation in Science Pursuit for Inspired Research (INSPIRE) Faculty Scheme and the Ramalingaswami Re-entry Fellowship Scheme.
- The launch of IPR Policy in 2016 has set a pace to resolve the IPR issues related to R&D in India.
- India is rapidly becoming a global design and developmental hub. Thousands of companies from around the world have set up their R&D centres in India.
- Change in immigration rules of developed countries like the United Kingdom and the United

States could be one of the reasons of Indian-origin scientists returning to India.

- It will boost quality R&D in India at various levels and thereby, positively impacting the higher education sector. It would result in indigenisation of science and technology and make India self-reliant in various fields.

1.10.2 Challenges to Brain Gain

- There is limited institutional capacity to absorb all interested Indian-origin scientists living abroad. Of the 373 scientists who got these scholarships between 2014 and 2016, only 125 were absorbed into their host institutions.
- Funding is another major obstacle for developing a favourable environment for quality research. India invests less than 1% of its GDP in scientific research.
- Micro-management of researchers and red-tapeism has plagued some of the top institutions of the country.
- A disconnect between labs and academia: There is limited coordination between colleges and research facilities. Apart from PhD students, hardly anyone is seen in labs conducting research.
- The research in India occurs in silos, there is lack of integrated approach. The culture of industry–academic collaboration in India has not developed at par with other developed countries.
- Government has not yet come up with a uniform and integrated policy for research and development, which could aggregate the efforts of various institutes.
- India has improved its overall International Intellectual Property (IIP), and the country is ranked 42nd out of 55 countries on the International Intellectual Property Index 2023.

1.10.3 Schemes for Brain Gain by DST

1. **Visiting Advanced Joint Research (VAJRA):** This scheme enables NRIs and overseas scientific community to participate and make its contribution for development of India. Under this scheme, Indian researchers who are residing abroad can collaborate with public-funded institutes. This scheme has covered a broad area of research, pertaining to topics like energy, health, and advanced material.
2. **Ramanujan Fellowship Programme:** This scheme is engineered to benefit all those Indian scientists who wish to return to India and start research in scientific institutes and universities in India.
3. **Ramalingaswami Re-entry Fellowship:** To encourage those scientists (Indian nationals) who are working outside the country and would like to return to India to pursue their research interests in Modern Biology, Biotechnology, Life Sciences and other related areas. The principal aim of the scheme is to improve the country's human resource capacity in Life Sciences, Modern Biology and Biotechnology research. As per the Annual Report 2022–23 of Department of Biotechnology, so far, 553 fellows have been supported under this programme, out of which 339 fellows have already secured permanent faculty positions in Indian institutions.
4. **Welcome Trust Fellowship Programme:** This scheme enables Indian scientists working abroad to return and pursue research in Indian universities and institutes.

1.11 RECENT INITIATIVE OF GOVERNMENT IN R&D

India, against a race with the developed nations of the world, is trying to create its own space. For this, India is making all-inclusive efforts. The most important arena for development for every developing country is science and technology, which in turn can promote overall development and can serve huge purpose. India, being the most populous country, has humongous human capital, which can be readily put to use, as shown by the demographic dividend of the country.

India has increased its spending on R&D and it is continuously showing upward trend, according to National Science and Technology Management Information System (NSTMIS). Considering the scenario and to promote young scientists and researchers, the Ministry of Science and Technology has recently launched many schemes. These are as follows:

1. **Teacher Associateship for Research Excellence (TARE):** The aim of this scheme is to tap the educators who are full of potential and willing to

pursue research, but unable to do so due to lack of guidance, facilities and funding. This scheme will enable educators to connect to public-funded institutions like IIT, IISc and NIT or national institutions like CSIR and ICAR to pursue research. This scheme is expected to benefit up to 500 teacher associates.

2. **Overseas Visiting Doctoral Fellowship (ODVF):** This scheme offers support to 100 Ph.D scholars for training in universities/laboratories abroad, for up to 12 months during their doctoral research.
3. **Distinguished Investigator Award:** This scheme offers a maximum of 100 fellowships to Principal Investigators of Science (PIS) and Engineering Research Board/Department of Science and Technology projects. The selected 100 researchers will be given a monthly fellowship of 15,000 for three years and an optional research grant, based on peer review of the project proposal submitted.
4. **Augmenting Writing Skills for Articulating Research (AWSAR):** The aim of this scheme is to encourage writing stories about scientific affair evolving out of a R&D lab in young scholars. This can be done through newspapers, magazines and journals. This scheme is willing to tap the potential of 20,000 Ph.D scholars to popularise and communicate their research outcome. The main aim of the scheme is to empower, recognise and motivate the youth.

1.11.1 Other Schemes Launched

1. **National Initiative for Developing and Harnessing Innovations (NIDHI):** The scheme was pioneered by DST for providing efficient environment by nurturing ideas and innovation and providing knowledge driven by technology for start-ups. This scheme targets major problems faced by India, i.e., wealth creation and will also open opportunity for the unemployed.
2. **Knowledge Involvement in Research Advancement through Nurturing (KIRAN):** The scheme is implemented by the DST. A unique advertising scheme to bring about, as far as possible, gender equality in the field of science and technology. This scheme aims to increase the number of women researchers, to attain gender parity. This scheme will enable those women to pursue research, who could not previously do it, owing to household reasons.
3. **Prime Minister's Research Fellowship Scheme (PMRFS):** In 2018, the cabinet has approved the implementation of PMRFS. This scheme is for doctoral students, pursuing research in areas related to technology.

Aim To realise the importance of innovation and technology for progress and development of the nation. Under this scheme, the best students who have completed their final year of B.Tech/Integrated M.Tech/M.Sc courses in Science and Technology streams from IISc/IITs/IIS ERs/NITs/IIITs will be offered direct admission in Ph.D programmes in IIT/IISc. This scheme is built on the model of PPP, between SERB (a statutory body formed by the Act of Parliament, for supporting basic research in the field of science and engineering) and DST.

Importance This scheme will help in pooling talent from across the country for carrying out research. These fellow researchers will hold the national priority topics in their hand.

1.12 ATAL INNOVATION MISSION (AIM)

- Atal Innovation Mission (AIM) including **Self-Employment and Talent Utilization (SETU)** is Government of India's endeavour to promote a culture of innovation and entrepreneurship. Its **objective** is to serve as a platform for promotion of world-class Innovation Hubs, Grand Challenges, Startup businesses and other self-employment activities, particularly in technology-driven areas.
- AIM is mandated to create an umbrella structure to oversee innovation ecosystem of the country and revolutionise the innovation ecosystem – touching upon the entire innovation life cycle through various programmes.

1.12.1 Core Functions of AIM

The Atal Innovation Mission shall have two core functions:

1. Entrepreneurship promotion through ***Self-Employment and Talent Utilisation***, wherein

innovators would be supported and mentored to become successful entrepreneurs.

2. ***Innovation Promotion:*** to provide a platform where innovative ideas are generated.

STUDENT ENTREPRENEURSHIP PROGRAMME

Atal Innovation Mission (AIM), NITI Aayog, in collaboration with **Dell Technologies** has launched **Student Entrepreneurship Programme 2.0 (SEP 2.0)** for young innovators of **Atal Tinkering Labs (ATLs)**.

About SEP 2.0 and its significance:

- It will allow student innovators to work closely with Dell volunteers.
- They will receive **mentor support; prototyping and testing support; intellectual property registration and patenting of ideas, processes, and products;** manufacturing support; as well as the launch support of the product in the market.

About Student Entrepreneurship Programme:

- **SEP 1.0 began in January 2019.**

- Atal Innovation Mission (AIM) including **Self-Employment and Talent Utilization (SETU)** is Government of India's endeavour to promote a culture of innovation and entrepreneurship.
- Its **objective** is to serve as a platform for promotion of world-class Innovation Hubs, Grand Challenges, Startup businesses and other self-employment activities, particularly in technology driven areas.

1.12.2 Impact of Atal Innovation Mission

- The Mission has undertaken many bold and forward-looking initiatives such as **Atal Tinkering Labs (ATL) and Atal Incubation Centres (AIC),** which have received great traction.
- Many ministries/departments of Government of India have initiated innovation related activities with the help and technical support of AIM.
- Under the ATL programme, more than 10,000 schools were established till 2020.
- More than 100 Atal Incubation Centres (AICs) are likely to be established around the country, supporting at least 50–60 startups each, over the first five years.
- More than 100 innovators/startups are expected to receive some support for productising their innovations.
- Each incubator is expected to foster 50–60 technology-driven innovative startups every four years.

1.12.3 Atal Tinkering Laboratories (ATLs)

With a vision to **'Cultivate one million children in India as Neoteric Innovators', Atal Innovation Mission is establishing 'Atal Tinkering Laboratories' (ATLs) in schools across India.**

Objective The objective of this scheme is to foster curiosity, creativity and imagination in young minds; and inculcate skills such as design mindset, computational thinking, adaptive learning, physical computing, etc.

Financial Support AIM will provide grant-in-aid that includes a one-time establishment cost of ₹10 lakh and operational expenses of ₹10 lakh for a maximum period of 5 years to each ATL.

Eligibility Schools (minimum Grade VI–X) managed by Government, local body or private trusts/society can set up ATL.

Need for Such Labs

- As the world grapples with evolving technologies, a new set of skills have gained popular acceptance and has come to be in high demand. For India, to contribute significantly during this age of rapid technological advancement, there is an urgent need to empower our youth with these 'skills of the future'.
- Equipped with modern technologies to help navigate and impart crucial skills in the age of the Fourth Industrial Revolution, the ATLs are at the vanguard of promoting the scientific temper and an entrepreneurial spirit in children today.

1.12.4 Atal Community Innovation Centre (ACIC) Programme

Atal Innovation Mission (AIM) launches **Atal Community Innovation Centre** (ACIC) Programme. ACIC programme aims at **spurring community Innovation in underserved and unserved areas of the country.** ACIC can serve as the bridge between the knowledge base existing in communities and the

advanced technical ecosystem prevalent in the market base, addressing the needs of society.

Features of the Programme

- ACIC is a new initiative of Atal Innovation Mission **to support community innovation drive in the country.**
- The programme is directed to encourage the spirit of innovation through solution-driven design thinking to serve the society.
- It will focus on underserved/unserved regions of the country, which at present lack a vibrant start-up and innovation ecosystem.
- **ACIC will be established either in PPP mode or with support of PSUs and other agencies.**
- The maximum grant-in-aid support form AIM will be up to 2.5 crores subject following compliance to ACIC guidelines.

1.12.5 Youth Co:Lab

Atal Innovation Mission (AIM), NITI Aayog, UNDP India jointly launch **Youth Co:Lab** *to* **accelerate youth-led social entrepreneurship and innovation in India.**

1. Youth Co:Lab will convene social innovation challenges at the national and sub-national level, which will invite young people in the **age group of 18–29 years** and start-ups to showcase their proposed ideas and solutions to tackle some of the region's biggest social challenges.
2. Through Youth Co:Lab, young entrepreneurs and innovators will get a chance to connect with governments, mentors, incubators and investors, who will help equip them with entrepreneurial skills.

The first phase of Youth Co:Lab will focus on six SDGs:

1. SDG 5 (Gender Equality).
2. SDG 6 (Clean Water and Sanitation).
3. SDG 7 (Affordable and Clean Energy).
4. SDG 8 (Decent Work and Economic Growth).
5. SDG 12 (Sustainable Consumption and Production).
6. SDG 13 (Climate Action).

What is Youth Co:Lab Initiative?

- It is an innovative platform for young people to explore their ideas and potentials and bring to scale viable solutions, to accelerate India's progress on the SDGs.
- **Co-created in 2017** *by UNDP* and the Citi Foundation.
- **Operational in 25 countries** across the Asia Pacific region.
- **Aims** to create an enabling ecosystem to promote youth leadership, innovation and social entrepreneurship.

Need for and Significance of This initiative?

- With the world's largest youth population millions in the county are entering the workforce every year, it is critical for India to create a robust employment and entrepreneurship ecosystem.
- Besides, 21st-century challenges can't be solved with traditional approaches.
- Therefore, it is essential to position young people in front and centre, to solve the region's most wicked development challenges. It is necessary to ensure that they are motivated and excited to learn future skills, particularly leadership, social innovation, entrepreneurship and communication.

2.1 ROLE OF SCIENCE AND TECHNOLOGY IN THE DEVELOPING WORLD IN THE TWENTY-FIRST CENTURY

Developments in science and technology are changing the means of people's lifestyles, communications and transactions. They also have an intense impact on economic development. For the promotion of tech-advanced life, developing countries must invest in quality education of their youngsters, while continuously striving to update workers' and managers' skills training as well.

Some entirely new sectors are emerging to mark technological revolutions in twenty-first century. These new sectors are telecommunication, biotechnology, microprocessor and nano-technology. Products are capable of transforming business practices of the economy.

With the development in medical services and education, technology can improve the conditions of poor people living in the developing and under-developed countries.

As an engine of growth, technology has endless potential, which is untapped to a greater extent in the developing world. There is a lack of skilled labour and capital in the underdeveloped countries. The difference in the per-capita income that is prevalent across nations is not only due to the difference in inputs but also due to the lack of ability for adoption as well as adaption of technologies for improving productivity.

For instance, computing has the ability to transform economic performance through unlocking of infrastructure backlogs and integrated supply chain management. It enables education and healthcare services to be accessible. The human experience has been transformed with the blend of computers and internet, mobile handsets and the emergence of cloud computing. It empowers individuals by providing them access to knowledge and markets.

Other developed technologies are cognitive augmentation, genetic engineering and proton cancer therapy. Examples of innovative inventions include underground small nuclear power units – termed as nuclear batteries – which are maintenance-free and ultra-safe; latest form of photovoltaics, which produce electricity with the help of sunlight and are cheaper than coal.

Management of technological revolutions poses many challenges. Bio-ethical issues will be raised as a result of certain discoveries and inventions, such as the development of genetically modified food crops and human cloning. Their cost, mainly in the early stages of development, is a big risk that is going to worsen the current inequality due to its restrictive availability to wealthy individuals. The same has already been occurring in the field of health care in certain G7 countries wherein expensive equipment for diagnosis and surgical procedures are straining the budgets allocated for public health and thereby, lowering the quality of service provided in poor neighbourhoods.

The climate of investment as well as the structures of right incentive is crucial, in order to guide the distribution of resources, as well as encouraging research and development.

The abilities of successful countries have grown by the way of innovation and learning through the investment of public funds for financing research and development in critical areas.

Those companies and countries which are adaptable to quickly shifting environment and quick enough to take the benefits of the opportunities, will grab the benefits arising from revolution of technology in an ever-increasingly connected and knowledge-intensive world. The successful countries will make significant progress towards the reduction of inequality and poverty.

2.2 MINISTRIES AND DEPARTMENTS FOR SCIENCE AND TECHNOLOGY UNDER CENTRAL GOVERNMENT

2.2.1 Department of Science and Technology (DST)

In May 1971, the Department of Science and Technology (DST) was established, with the main objective of promoting new areas of science and technology. It is a nodal department for organising, coordinating and the promotion of science and technology activities in the country. This department is responsible for specific

projects and programmes, some of which are listed below:

1. Formulation of policies related to Science and Technology.
2. Issues concerning the Scientific Advisory Committee of the Cabinet (SACC).
3. Promoting new areas of Science and Technology, which specially emphasised on emerging areas.
4. Coordination and integration of areas of Science and Technology having cross-sectoral linkages in which scientific research institutions, scientific association and bodies are supported and also gives grants.
5. All matters concerning:
   - Science and Engineering Research Board;
   - Technology Development Board and its related Acts, such as the Research and Development Cess Act, 1986, and the Technology Development Board Act, 1995;
   - National Council for Science and Technology Communication;
   - National Science and Technology Entrepreneurship Development Board;
   - Science and Technology Cooperation under international level, including appointment of scientific attaches abroad (these functions shall be exercised in close cooperation with the Ministry of External Affairs);
   - Different autonomous institutions under the Department of Science and Technology, including Institute of Astrophysics and Institute of Geomagnetism;
   - Promotion of National Spatial Data Infrastructure;
   - Professional science academies that are promoted and funded by the Department of Science and Technology;
   - The Survey of India and National Atlas and Thematic Mapping Organisation;
   - Promotion of G.I.S;
   - The National Innovation Foundation, Ahmedabad.
6. Manage and coordinate information systems for science and technology.
7. Matters concerning to inter-agency/inter-departmental coordination for evolving science and technology missions.
8. The promotion and application of science and technology for the development and security of the nation.
9. Matters relating to institutional science and technology, which enhances capacity building through setting up of new institutions and developing infrastructure.
10. Promotion of science and technology for grassroots development at the state, district and village levels.
11. Application of science and technology for weaker sections, women and other disadvantaged sections of the society.

2.2.1.1 Programmes Under DST

Inspire/Inspiring Creativity and Innovation

The steadily dropping enrolment in science streams over the past few years has been a cause of concern for educationists and policy makers alike. Similar concern has been voiced with regard to motivating the youth to venture into the field of creative scientific innovations. The progress of a nation largely depends on creativity, scientific research and innovation.

With a view to create an interest among the students for science and motivate them to develop innovative ideas, the Department of Science and Technology (DST), Government of India, started the 'INSPIRE Programme'. INSPIRE or Innovation in Science Pursuit for Inspired Research *(https://online-inspire.gov.in/)* is a unique programme that aims to inspire young talent towards advanced studies and research in basic sciences, thus, strengthening and building the national science and technology base.

The most significant feature of the programme is that it does not believe in conducting competitive exams to distinguish talent at any level. Rather, it relies on the efficacy of the already existing educational structure to identify talent. Simultaneously, it also involves academia, scientific community/industry, state functionaries and other stakeholders to spread scientific temperament among the youth.

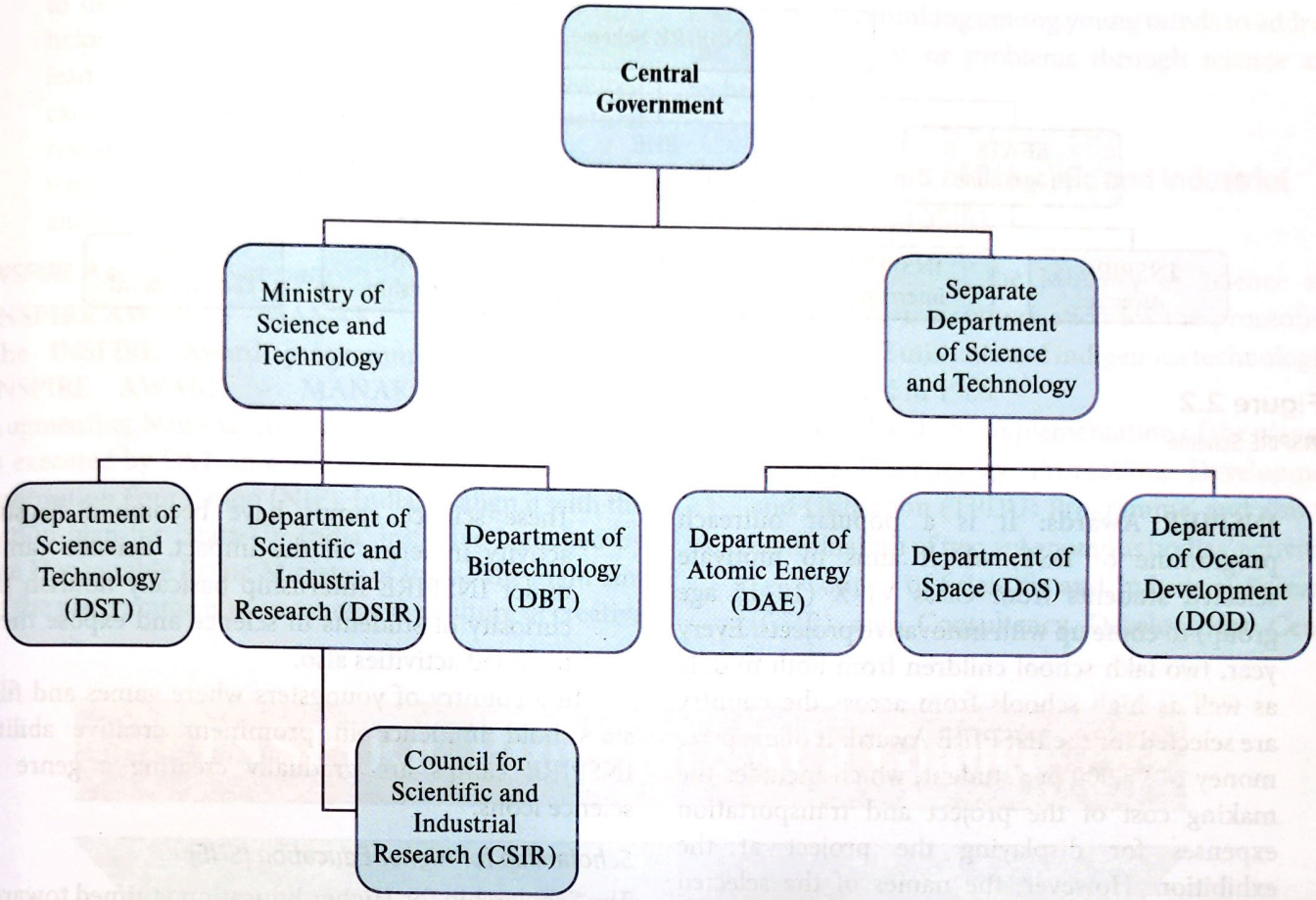

Central Government
Ministry of Science and Technology
Separate Department of Science and Technology
Department of Science and Technology (DST)
Department of Scientific and Industrial Research (DSIR)
Department of Biotechnology (DBT)
Department of Atomic Energy (DAE)
Department of Space (DoS)
Department of Ocean Development (DOD)
Council for Scientific and Industrial Research (CSIR)

Figure 2.1
The Science and Technology departments functioning under the Central Government

The programme covers the age group in the range of 10–32 years, and its components comprise the following:

1. Scheme for Early Attraction of Talent (SEATS)
2. Scholarship for Higher Education (SHE)
3. Assured Opportunity for Research Careers (AORC)

INSPIRE Scheme

The five subcomponents of the scheme are:

I. **INSPIRE Award:** This is for the age group of 10–15 years.
II. **INSPIRE Internship:** For the age group of 16–17 years, at a science camp, with a chance to interact with global leaders in the field of science.
III. **INSPIRE Scholarship for Higher Education (SHE):** For the 17–22 year age group, ₹80,000 per year for continuing education at Bachelor of Science and Master of Science levels.
IV. **INSPIRE Fellowship:** For doctoral research (For the age group of 22–27 years).
V. **INSPIRE Faculty:** For assuring career opportunity (For the age group of 27–32 years).

The scheme's first component, INSPIRE awards, is centrally implemented with the help of states/UTs while the scheme's other components are implemented centrally with the help of DST, through the academic/research institutes and universities concerned, etc.

Scheme for Early Attraction of Talent (SEAT)

The scheme provides a platform to millions of students to portray their creativity where they can experiment and innovate. Under this scheme, students in the age group of 10–15 years are provided with financial assistance to experience the joy and innovation in science. Young minds are also presented with INSPIRE Awards and are exposed to INSPIRE Internships, summer/winter camps.

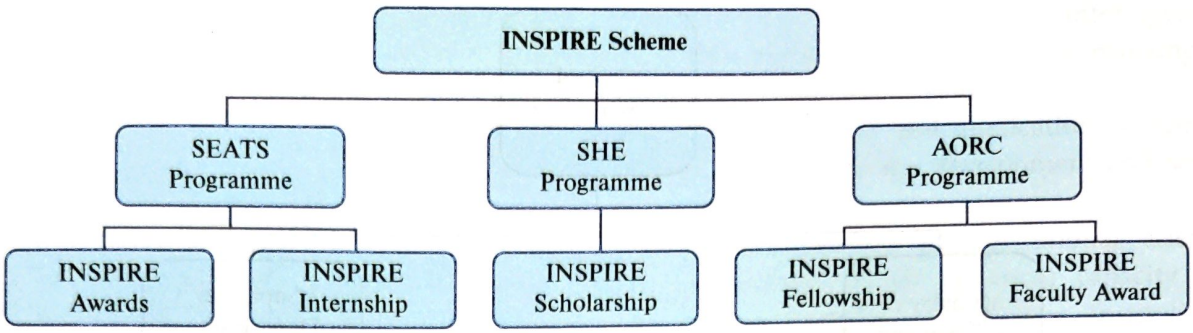


Figure 2.2
INSPIRE Scheme

- **INSPIRE Awards:** It is a popular outreach programme of DST, which aims to motivate selected students from Class VI–X (10–15 age group) to come up with innovative projects. Every year, two lakh school children from both middle as well as high schools from across the country are selected for the INSPIRE Award. It offers prize money of ₹5,000 per student, which includes the making cost of the project and transportation expenses for displaying the project at the exhibition. However, the names of the selected students are nominated by the school principal/ headmaster/headmistress.

  The selected students take part in a three-tier competition at district, state and national levels. The jury members evaluate the exhibited projects. All schools in the country, recognised by the respective district/state education authorities, irrespective of whether government or privately operated, aided or unaided, funded by the central or the state governments or local bodies, and having classes VI–X are covered under the scheme.
- **INSPIRE Internship:** This component of the Scheme for Early Attraction of Talent aims to provide exposure to young science students through organising science camps, either in the summer or winter season. Every year, around 50,000 aspiring students who are among the top 1% in their Class X and are pursuing science in Class XI are invited to participate in the five-day science camp. In doing so, students get a chance to interact with eminent science icons of national and international repute, including Nobel Laureates.

  These science camps have become a flagship activity in terms of the impact. Science camps under INSPIRE Internship basically nourish the curiosity of students in science and expose them to varied activities also.

In a country of youngsters where games and film stars hold influence in prominent creative ability, INSPIRE camps are gradually creating a genre of science icons.

Scholarship for Higher Education (SHE)

The Scholarship for Higher Education is aimed towards driving young students towards science – intensive programmes through providing scholarships and mentoring. Scholarship is a boon for those who are unable to continue their education. The scheme offers ₹10,000 scholarships annually, with each valued at ₹80,000, to young minds in the age group of 17–22 years, for opting natural and basic sciences in Bachelors and Masters level.

Assured Opportunity for Research Careers (AORC)

This programme is for assuring career opportunities to those interested in a career in the R&D sector. It consists of:

- **INSPIRE Fellowships:** This is focussed on students of the age group 22–27 years, who want to pursue a doctoral degree in basic and applied sciences, including engineering, medicine, etc. The fellowships are provided to the first ranker in basic and applied sciences as well as INSPIRE scholars, who secure 65% marks in aggregate at PG level.
- **INSPIRE Faculty Scheme:** This helps young researchers who are in the age group of 27–32 years

to develop an independent scientific profile and helps them to emerge as science and technology leaders. Every year, this scheme provides assured career opportunities to 1000 post-doctoral researchers by offering both contractual as well as tenure track positions for five years in both basic and applied sciences.

INSPIRE Programme Summary

INSPIRE AWARDS – MANAK

The INSPIRE Award programme is renamed as INSPIRE AWARD – MANAK (Million Minds Augmenting National Aspiration and Knowledge) and is executed by DST, in coordination with the National Innovation Foundation (NIF), India, to align it with the action plan for 'Start-Up India' initiative launched by the Honourable Prime Minister of India. The main aim of the programme is to encourage the culture of creative and innovative thinking among young minds to address the societal needs or problems through science and technology.

2.2.2 Department of Scientific and Industrial Research (DSIR)

DSIR is a division of the Ministry of Science and Technology with the authorisation for the promotion, development and utilisation of indigenous technologies. It was established in 1986.

- It is tasked with the implementation of the planned scheme 'Technology Promotion, Development and Utilisation (TPDU) Programme' and also the coordination of two autonomous bodies' activities, i.e., Council of Scientific and Industrial Research (CSIR) and Consultancy Development Centre

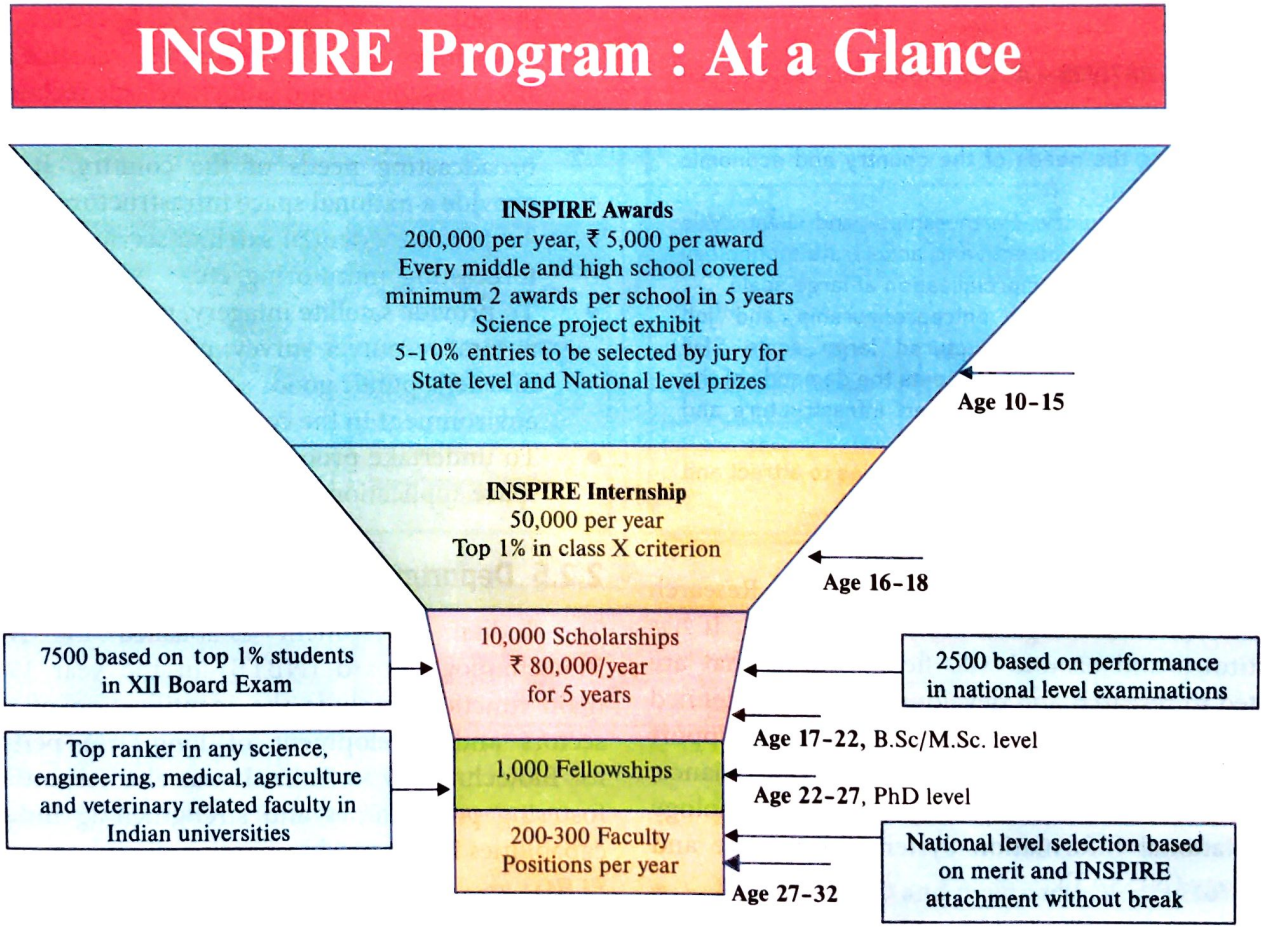

INSPIRE Program : At a Glance
INSPIRE Awards
200,000 per year, ₹ 5,000 per award
Every middle and high school covered
minimum 2 awards per school in 5 years
Science project exhibit
5-10% entries to be selected by jury for
State level and National level prizes
Age 10-15
INSPIRE Internship
50,000 per year
Top 1% in class X criterion
Age 16-18
7500 based on top 1% students in XII Board Exam
10,000 Scholarships
₹ 80,000/year
for 5 years
2500 based on performance in national level examinations
Age 17-22, B.Sc/M.Sc. level
Top ranker in any science, engineering, medical, agriculture and veterinary related faculty in Indian universities
1,000 Fellowships
Age 22-27, PhD level
200-300 Faculty Positions per year
National level selection based on merit and INSPIRE attachment without break
Age 27-32

Figure 2.3
INSPIRE Programme Summary

(CDC) and two public-sector undertakings, i.e., National Research Development Corporation (NRDC) and Central Electronics Limited (CEL).

- Consultancy Development Centre (CDC) is an independent institution working under the Department of Scientific and Industrial Research, Ministry of Science and Technology and the Government of India.

Objective To promote and develop consultancy.

2.2.2.1 Council of Scientific and Industrial Research (CSIR)

It is an autonomous, non-profit, publicity funded R&D organisation under the Department of Scientific and Industrial Research, Ministry of Science and Technology. It was established in 1942.

Objective To maximise the economic, environmental and societal benefits of Indian people through scientific and industrial R&D.

CSIR INITIATIVES – ADDRESSING EMERGING NEEDS

- Leveraging Science, Technology and Innovation (STI) for meeting the needs of the country and economic value creation.
- Enhancing Industry Partnerships and Last Mile Linkages: with the objective to accelerate technology deployment and commercialisation at large scale.
- Enhancing S&T-based entrepreneurship and job creation to build a structured large scale Skill Development Initiative that meets the demands of the country using the state-of-the-art infrastructure and human resources of CSIR.
- Progressive Human Resources Policies to attract and retain the best talents.

The Council of Scientific and Industrial Research (CSIR) is the major organisation under DSIR. It has 40 institutes and around 100 field stations that are dedicated to research and development in well-defined areas. Some other programmes are providing support in R&D by industry, technological self-reliance, schemes to enhance efficacy of transfer of technology and a National Information System for Science and Technology (NISSAT).

2.2.3 Department of Atomic Energy (DAE)

The department was set up on 03 August 1954 under the direct control of the then Prime Minister, through a Presidential Order. Through a resolution, the Atomic Energy Commission was constituted and the Secretary to the Government of India in the Department of Atomic Energy is declared as the ex-officio Chairman of the Atomic Energy Commission. DAE is concerned with nuclear power technology development and its uses in the medicine, agriculture, basic research and industrial fields.

2.2.4 Department of Space (DoS)

The main objective of Department of Space (DoS) is the promotion of space science and technology development, towards the achievement of becoming self-reliant and advance space applications so as to facilitate the overall nation's development.

The objectives of Department of Space are:

- To achieve the goal of total self-reliance through R&D in satellite and launch-vehicle technology.
- In order to fulfil the telecommunications and broadcasting needs of the country. It aims to provide a national space infrastructure.
- To provide essential satellite services for weather forecasting, monitoring, etc.
- To provide satellite imagery, which is used for the natural resources survey, management of natural disasters, public goods services and monitoring of environment in the country.
- To undertake proof of concept demonstration of space applications.

2.2.5 Department of Biotechnology (DBT)

The Indian government established the National Biotechnology Board (NBTB) in the year 1982. Its main functions include the identification of priority sectors and development of long-term perspective for Biotechnology in India. It was also responsible for fostering programmes and strengthening indigenous capabilities in this newly emerging discipline.

MANY A FIRST – CSIR LEADING AND PAVING THE WAY

- First to develop baby milk powder from buffalo milk with excellent digestibility.
- First to develop indelible ink used in election for indelible mark.
- First to develop non-steroidal once a week oral contraceptive pill 'Saheli' for women.
- First to develop indigenous tractor Swaraj – leading a helping hand in the Green Revolution.
- First ever flowering of tissue-cultured bamboo with the discovery of one of the smallest protein molecules – seminal plasmin.
- First to extract poly-metallic nodules from the ocean bed.
- First to build an all-composite small aircraft (Hansa) and 5-seater multipurpose aircraft CNM-5.
- First of its kind broad spectrum reflectance spectroscopy based confocal microscope using super continuum light source.
- First in world bio-processing technology for leather, leading to paradigm shift in leather processing.
- First hand-held battery operated micro PCR – patented in over 100 countries.
- First of its kind portfolio of Streptokinase – a vital, life save injectable drug for cardiac problems.
- First of its kind DNA-based Macro Chip for detection of eye infection – covering different organisms in one test within seven to eight hours, as compared to the conventional 3–7 days.

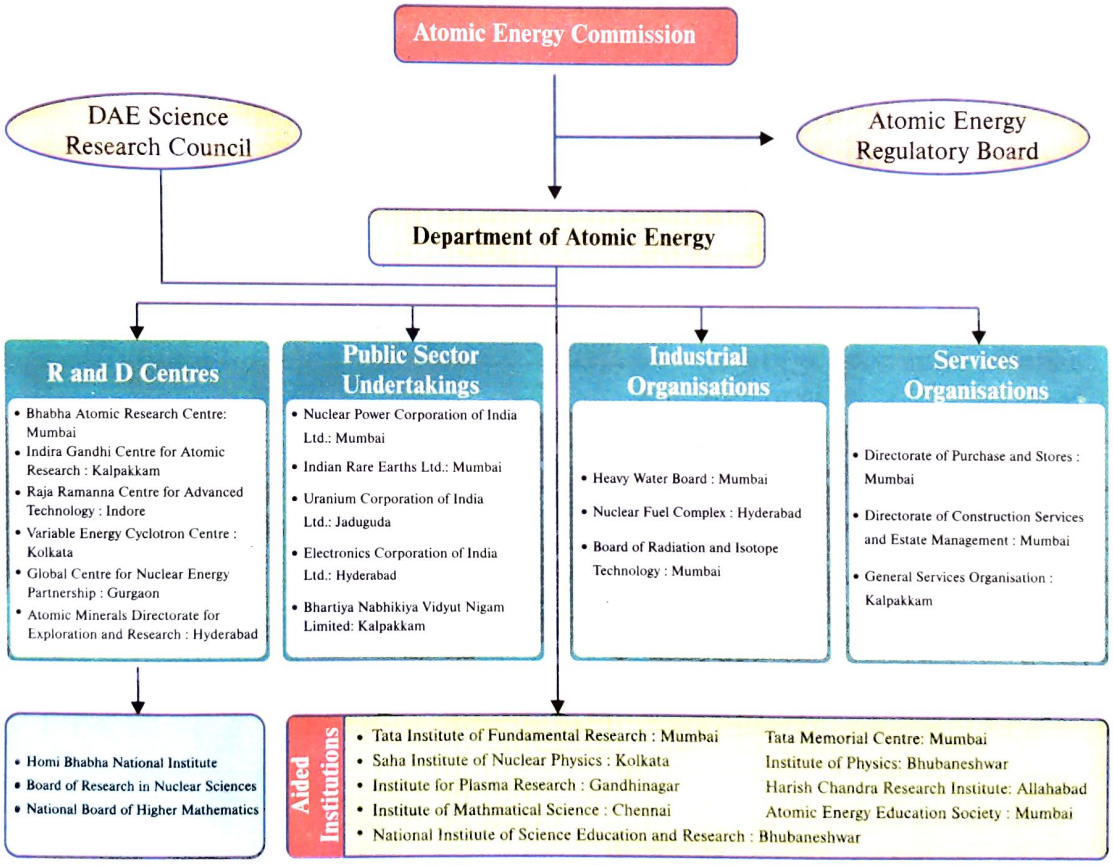

Atomic Energy Commission
DAE Science Research Council
Atomic Energy Regulatory Board
Department of Atomic Energy
R and D Centres
Bhabha Atomic Research Centre: Mumbai
Indira Gandhi Centre for Atomic Research : Kalpakkam
Raja Ramanna Centre for Advanced Technology : Indore
Variable Energy Cyclotron Centre : Kolkata
Global Centre for Nuclear Energy Partnership : Gurgaon
Atomic Minerals Directorate for Exploration and Research : Hyderabad
Public Sector Undertakings
Nuclear Power Corporation of India Ltd.: Mumbai
Indian Rare Earths Ltd.: Mumbai
Uranium Corporation of India Ltd.: Jaduguda
Electronics Corporation of India Ltd.: Hyderabad
Bhartiya Nabhikiya Vidyut Nigam Limited: Kalpakkam
Industrial Organisations
Heavy Water Board : Mumbai
Nuclear Fuel Complex : Hyderabad
Board of Radiation and Isotope Technology : Mumbai
Services Organisations
Directorate of Purchase and Stores : Mumbai
Directorate of Construction Services and Estate Management : Mumbai
General Services Organisation : Kalpakkam
Homi Bhabha National Institute
Board of Research in Nuclear Sciences
National Board of Higher Mathematics
Aided Institutions
Tata Institute of Fundamental Research : Mumbai
Saha Institute of Nuclear Physics : Kolkata
Institute for Plasma Research : Gandhinagar
Institute of Mathmatical Science : Chennai
National Institute of Science Education and Research : Bhubaneshwar
Tata Memorial Centre: Mumbai
Institute of Physics: Bhubaneshwar
Harish Chandra Research Institute: Allahabad
Atomic Energy Education Society : Mumbai

Figure 2.4
The Organisational Structure of the Atomic Energy Commission

A separate **Department of Biotechnology (DBT)** was established in February 1986 for the following functions:

- Popularise Biotechnology for large-scale use;
- Promote R&D and manufacturing in Biology;
- Enhance industry and university interaction;
- Identify and establish R&D centres for promoting technology in this field;

- Popularise Human Resource Development programmes;
- Act as a nodal agency for some specific international collaboration;
- Improve bio-safety guidelines.

2.2.6 Department of Ocean Development (DOD)

This department was setup in July 1981 as an organ of the Cabinet Secretariat, which is directly under the charge of the Prime Minister and in March 1982, became an independent department. Earlier, it performed as a nodal ministry for organising, coordinating and also promoting ocean development activities in the country. In February 2006, the DOD was upgraded as the Ministry of Ocean Development (MoOD) by the Government of India. On 12 July 2006, Government of India formed The Ministry of Earth Sciences (MoES) by merging of the Ministry of Ocean Development (MoOD), India Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM), National Centre for Medium Range Weather Forecasting (NCMRWF) and Earth Risk Evaluation Centre (EREC).

2.2.7 Indian Council of Medical Research (ICMR) – Strategic Plan and Agenda 2030

In 2017, ICMR developed its Strategic Plan and Vision 2030 document. It is conceptualised on five primary pillars:

1. Strengthen health research capacity in the country.
2. Organise data systems and research platforms.
3. Leverage traditional medicine.
4. Enable evidence to policy translation.
5. Strengthen programme implementation through research.
    - ICMR's research priorities and projects are well-aligned and harmonised with the National Health Policy (NHP) 2017. In recent years, ICMR has also focussed on diseases targeted for elimination (Kala-azar, Filariasis, Leprosy, Malaria, HIV/AIDS and Tuberculosis), child and adolescent health, universal immunisation, communicable diseases.
    - ICMR has initiated a mission mode project on Tuberculosis, namely **'India TB Research**

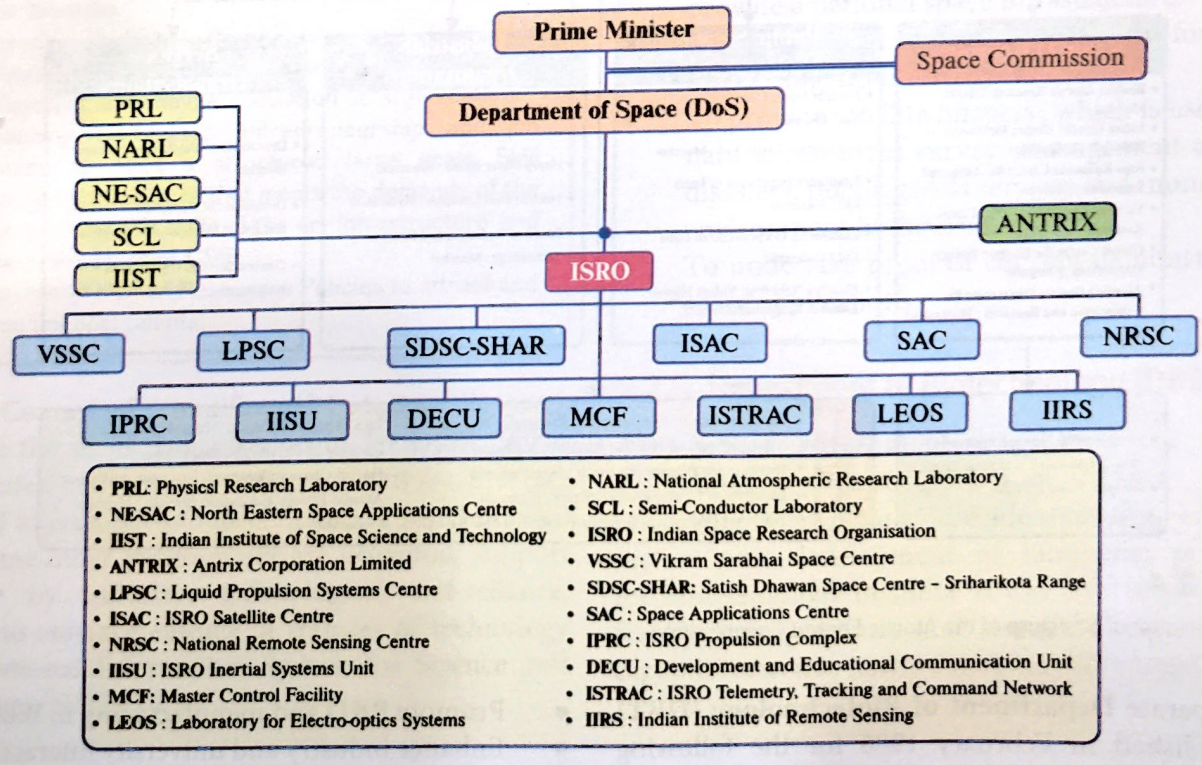


Figure 2.5
Space Organisation in India

Consortium (ITRC)' to boost TB elimination efforts, which has been sanctioned ₹139 crore from the government of India.

- With a target of Tuberculosis elimination by 2025, another ambitious pilot project is focussing on active case finding in five states for bridging the gap in the last mile delivery of services amongst tribal populations using 35 mobile TB diagnostic vans under the TIE-TB project.
- ICMR is also working closely with the National AIDS Control Organisation and is committed to the global call to **'End AIDS' by 2030.**

2.3 SCIENCE AND TECHNOLOGY POLICIES IN INDIA

The various science and technology policies in India are listed as follows:

1958	First scientific policy resolution of India.
1983	The main goal of the policy was to attain technological competency and self-reliance.
2003	This new policy wanted to – (i) Bring science and technology together. (ii) Bring higher investment into R&D for addressing national problems.
2013	This policy was framed by the Department of Science and Technology.
2010–2020	Indian policy has been acknowledged as 'decade of innovation'.

2.3.1 Science, Technology and Innovation (STI) Policy, 2013

It was unveiled in 2013 by the then Prime Minister at the science congress at Kolkata to use science, technology and innovation for faster, sustainable and more inclusive growth, along with focus on both STI for people and people for STI, for positioning India among the top five global scientific powers by 2020, to encourage private sector's investment in Research and Development (R&D), for achieving gender parity in science and technology and Global cooperation and science diplomacy.

2.3.1.1 Goals

(a) The main policy goal is Science, Research and Innovation System for High Technology led path for India (SRISHTI).

(b) Combination of science, research and innovation systems and the country's development as one of the top five major world's science knowledge powers.

(c) A dedicated Policy Research Cell is established by the Department of Science and Technology.

2.3.1.2 Highlights of STI Policy, 2013

- India has declared 2010–20 as the 'Decade of Innovation' (innovation refers to science and technology-based solutions that are deployed in the economy or society).
- Policy is based on the fundamental idea that though science, technology and innovation can exist separately on their own disconnected spaces, their integration leads to new value creation. The new paradigm emphasises STI for people, by recognising society as its major stakeholder.
- Special focus is provided for attaining inclusive growth, which ensures access, availability and affordability of innovative solutions, for people who are especially at the bottom of the pyramid (social and economic).
- Key objectives of the policy are promoting scientific temper, enhancing skills, creating new career opportunities in science, establishing quality infrastructure, creating a robust innovation system and positioning India among the top five global powers.
- The policy recommends increasing the gross expenditure on research and development to 2% of the GDP, with the support of private and public sectors.
- According to the policy, India ranks ninth globally in the number of scientific publications; composite annual growth rate of Indian publications is around 12% and India's global share has increased from 1.8% in 2001 to 3.5% in 2011. But, the percentage of Indian publications in the top 7% impact-making journals is only 2.5%. The policy aims at doubling the number of high impact papers by 2020.

- The policy framework will focus on reforms in school science education, by improving teaching methods, science curricula and introducing schemes for early alteration of talent to science. Additional efforts will also be taken for encouraging women and enabling them to choose a career in science.
- Transparent, centrally implementable, performance-related incentive schemes would be introduced.
- Efforts will be taken to ensure that benefits of innovation are provided to important sectors such as manufacturing, service, agriculture and also for handling the challenges of climate change.
- For encouraging private investment, PPP made with provisions for benefit sharing, modifying IPR policy for social goods, new mechanisms for incubating science-led enterprises and incentives for commercialising innovations with focus on green manufacturing, will be taken.
- Appropriate delivery system for diffusing scientific output and technological interventions into a social system through a multi-layered process will also be undertaken.
- A new regular framework will be put in place in order to gain global competitiveness through multiple collaborations.
- Public understanding of science is an important dimension for introducing and reaching the benefits of modern science and technology to the people. Platforms will be created for encouraging public debates based on evidence. Also, social scientists will be given an opportunity to assess the relevance of innovation through a robust evaluation system.

2.3.1.3 Criticism of STI Policy, 2013

- **Role of private sector:** The focus of private sector during investment in R&D is profitability; delivery of social goods is not their priority.
- **Indian private sector is lazy in research:** Private sector does not invest much in R&D compared to other counterparts, although the government is offering various tax incentives to Indian corporates for more investment and more research.
- **No lesson from past:** No analysis/reasons are provided by the new STI policy as to why the last three policies failed.
- **No structural/fundamental reforms:** To break the stalemate in research, higher education in the country needs a reform, which includes funding and autonomy of universities, IIMs, IIITs, etc.
- **Conflicting goals and policies:** Policy document has repeatedly emphasised that both economic growth and social good will be pursued through STI.

2.3.2 Science, Technology and Innovation Policy, 2020

The formulation process of Science, Technology and Innovation Policy, 2020 (STIP 2020) will be facilitated jointly by the Office of the Principal Scientific Adviser to the Government of India and the Department of Science and Technology (DST).

A participative model with four interconnected tracks has been envisioned to formulate the STIP 2020. The details on various tracks and the entire process is given below.

Track I aims to create a repository of public voices that will act as a guiding force for the drafting process.

Track II consultations comprise of 21 expert-driven thematic collectives to feed evidence-based recommendations into the policy drafting process.

Track III brings together Ministries and States in extensive engagement through nominated nodal officers.

Track IV is the binding force that draws upon apex level multi-stakeholder engagement at the national and global levels. Inputs from these wide-ranging deliberations will finally lead to STIP 2020.

2.4 NATIONAL AYUSH MISSION (AYUSH: AYURVEDA, YOGA, SIDDHA, UNANI AND HOMEOPATHY)

The Government of India has launched National AYUSH Mission (NAM) during 12th Plan, under Ministry of Health and Family Welfare.

The word AYUSH is derived from Sanskrit, meaning 'life'. AYUSH stands for the Department of Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy.

2.4.1 Objective

- Its main objective is to give universal access to AYUSH health care across the nation.
- Other objectives include strengthening of institutional capacity at state level, supporting cultivation of medicinal plants by adopting good agricultural practice.

2.4.2 Components of the Mission

2.4.2.1 Mandatory Components

1- AYUSH Service	2- Educational Institutions
3- Quality Control of AYUSH	4- Medicinal Plants

2.4.2.2 Flexible Components

1. AYUSH wellness centre including Yoga and Naturopathy
2. Tele-medicine
3. Sports medicine through AYUSH
4. Innovation of AYUSH through PPP model
5. Component of interest subsidy for private AYUSH educational instructions
6. Research and development in areas related to medicinal plants
7. Voluntary certification scheme
8. Crop insurance for medicinal plants

2.4.3 Institutional Mechanism

At national level, it is administered by National AYUSH Mission directorate, which consists of nine members.

The mission will be assisted by a National AYUSH Mission Appraisal Committee, which will be responsible for reviewing the State Annual Action plan (SAAP).

At state level, it is administered and executed by the State AYUSH Mission Society.

2.4.4 Resource Allocation

- Programme Management Unit (PMU) will be provided for strengthening the infrastructure of the mission and assistance will be given by both the Centre and the State. PMU consists of management and technical professionals.
- For AYUSH services, grant-in-aid would be provided for special category states [North-Eastern States, and three hilly States of HP, J&K (now UTs) and Uttarakhand] in the ratio of 90:10 (90% by the Centre and 10% by the State). For other state/ UTs, it will be 75:25.
- For medicinal plants, special category states are 100% financed by central government whereas it will be shared in 90:10 ratio in other states.

2.4.5 Expected Effect of the Mission

1. It will improve AYUSH education through upgraded AYUSH educational institutions.
2. Universal access to AYUSH hospitals and availability of drugs.
3. Encourage the traditional knowledge of AYUSH.

2.5 STEM EDUCATION: STRENGTHENING POLICIES FOR FUTURE SKILLED WORKFORCE

- There are certain lacunae in the education system in the country due to which it is becoming difficult to produce skilled workforce.
- Though the Indian school curriculum is strong with respect to basic science and mathematics content, but not good enough neither in case of engineering nor technology.
- In today's highly competitive world, STEM or **Science, Technology, Engineering and Mathematics education** is in high demand with industries.

- The Indian education system has become the largest and most complex in the world, with about 26 crore children enrolled in classes I to XII.
- The National Policy on Education 2016 during the 12th Five-Year Plan recognised education as the most important tool for social, economic and cultural transformation and emphasised on innovation, critical thinking and skill development.
- The New Education Policy (NEP) approved by the Union Cabinet on July 29th, 2020 emphasises on schools to have more experiment-based classes and hand-on learning. It also recognises that evidence-based learning, scientific temper and coding skills should be imparted in the students.
- Introduction of coding from class 6 onwards is a very welcome step which will strengthen STEM learning. Artificial Intelligence (AI), Block Programming will be incorporated in school education that will lay a solid foundation for key skills required for 21st century careers.

2.5.1 Stem Education and Challenges

- The Indian education system is facing more challenges as compared to other developed nations due to its cultural diversity and huge population. Despite the Right to Free and Compulsory Education (RTE) Act, 2009 poor infrastructure, lack of quality teachers, overhaul of the science curriculum and the failure to identify early talent and provide them with specialised education are some key points that need to be taken care of to improve STEM education in India.
- There are large numbers of dropouts from the science stream at the high school level. The parallel business of tuition/coaching classes is a clear index of the lack of credibility of the school system.

2.5.2 Operation of the Scheme

- The primary scheme will be operated in conjunction with National Apprenticeship Promotion Scheme (NAPS) which provides for placing of apprentices up to 10% of the total work force in every business/ industry.
- The scheme will be implemented by the Sector Skill Councils (SSCs), initially the Banking Finance Insurance Services (BFSI), Retail, Health care, Telecom, Logistics, Media, Management services, ITeS and Apparel. More sectors would be added over time with emerging apprenticeship demand and curriculum adjustments.

2.6 RECENT SCHEMES ANNOUNCED BY GOVERNMENT

2.6.1 Impacting Research, Innovation and Technology (IMPRINT)

IMPRINT is a **Ministry of Human Resource Development (MHRD) nationalized scheme**, intended to cater all main challenges of engineering significant to country during a comprehensive and sustainable approach of translational research.

IMPRINT is first of its kind MHRD supported scheme to address major science and engineering challenges and boost original scientific and technological research in 10 technology identified domains in the country. It was launched in November 2015 with an aim to develop new engineering education policy and create road map to pursue engineering challenges. These 10 domains are *Health Care, Computer Science and ICT, Advance Materials, Water Resources and River Systems, Sustainable Urban Design, Defence, Nano-Technology Hardware, Environmental Science and Climate Change and Energy Security.*

IMPRINT provides overarching vision that guides research into areas that are predominantly socially relevant. Initially under IMPRINT-I, IITs and IISC, were asked to identify major areas where India is facing engineering and technological challenges. Now its scope also has been expanded to private institutions along with IITs and IISC under IMPRINT-II and jointly funded and steered by MHRD and Department of Science and Technology (DST). The implementation of 142 projects under IMPRINT-I are already underway. These projects have received support from several ministries, councils and departments in addition to MHRD.

IMPRINT-II has been approved by Government of India (GOI) with **a revised strategy under which, this national initiative will be jointly funded and steered by MHRD and Department of Science and Technology (DST).**

- While any faculty member from an MHRD funded Higher Education Institute (HEI) including Centrally Funded Technical Institution (CFTI)

may lead as the Principal Investigator (PI), single or multiple partners from stake holder ministry, institutions, PSUs, strategic agencies and industry are welcome as Co-PI, partner or collaborator.

- IMPRINT II solicited innovative idea-based translational project proposals promising development of viable technology (product, process or prototype).
- IMPRINT-II: For advancing research in the higher education institutions, the government has approved 122 new research projects at a cost of ₹112 crore under IMPRINT-II covering energy, security, healthcare, advanced materials, ICT and Security/Defence domains.
- In December 2018, MHRD and DST launched the next round of IMPRINT II, called IMPRINT IIC (Societal Mission Projects) with an aim to seek proposals related to 20 very specific technology development themes of major societal relevance/ benefit, selected from the proposals sent by various partner ministries.

2.6.2 NIDHI (National Initiative for Developing and Harnessing Innovations)

The Department of Science & Technology, Government of India has launched NIDHI (National Initiative for Developing and Harnessing Innovations) as an umbrella programme under which programmes for setting up of incubators, seed fund, accelerators and 'Proof of concept' grant for innovators and entrepreneurs have been launched.

Under NIDHI, PRAYAS (Promoting and Accelerating Young and Aspiring Innovators & Startups) programme has been initiated in which established Technology Business Incubators (TBI) are supported with PRAYAS grant to support innovators and entrepreneurs with grants for 'Proof of Concept' and developing prototypes.

2.6.2.1 Entrepreneurs in Residence (EIR) Programme

- Entrepreneurs-in-Residence (EIR) Programme is one of the programmes introduced under NIDHI which was launched in 2020.
- It supports aspiring or budding entrepreneur of considerable potential for pursuing a promising technology business idea over a period up to 18 months with a subsistence grant up to ₹30000 per month with a maximum cap for total support of ₹3.6 lakh to each EIR over a maximum of 18 months.

2.7 INDIAN SCIENCE CONGRESS ASSOCIATION

The Indian Science Congress Association was ***started in the year 1914 in Kolkata and has a membership of more than 30,000 scientists.*** It owes its origin to the foresight and initiative of ***two British chemists, namely, Professor J.L. Simonsen and Professor P.S. MacMahon.*** They thought that scientific research in India might be stimulated if an annual meeting of research workers somewhat on the lines of the British Association for the Advancement of Science could be arranged.

Objectives

1. To advance and promote the cause of science in India.
2. To hold an annual congress at a suitable place in India.
3. To publish such proceedings, journals, transactions and other publications as may be considered desirable.
4. To secure and manage funds and endowments for the promotion of science including the rights of disposing of or selling all or any portion of the properties of the association.
5. To do and perform any or all other acts, matters and things as are conductive to, or incidental to, or necessary for, the above objects.

108th Indian Science Congress recently held at the Nagpur focussed on sustainable development with inclusive involvement of all sections of society including women.

Theme: 'Science & Technology for Sustainable Development with Women Empowerment'.

Indian Science Congress is organised by ***the Indian Science Congress Association*** every year in the first week of January.

2.8 NATIONAL SCIENCE DAY

28th February is celebrated as National Science Day (NSD) in India. NSD is celebrated to commemorate discovery of the **'Raman Effect'**, which led to Sir C.V.

Raman winning the Noble Prize. The **first National Science Day** was celebrated on February 28, 1987.

Theme The theme for National Science Day 2023 was 'Global Science for Global Wellbeing'.

RAMAN EFFECT

- A phenomenon in spectroscopy was discovered by the eminent physicist Sir Chandrasekhara Venkata Raman in 1928.
- Raman Effect is **a change in the wavelength of light that occurs when a light beam is deflected by molecules.**
- When a beam of light traverses a dust-free, transparent sample of a chemical compound, a small fraction of the light emerges in directions other than that of the incident (incoming) beam.
- Most of this scattered light is of unchanged wavelength. A small part, however, has wavelengths different from that of the incident light; its presence is a result of the Raman Effect.

2.9 SOME AUTONOMOUS INSTITUTIONS ENGAGED IN BASIC AND APPLIED SCIENCES RESEARCH

1. **Bose Institute, Kolkata:** Devoted to fundamental and applied research in physical and life sciences.
2. **Agharkar Research Institute, Pune:** Research in basic and applied aspects in the field of biological sciences.
3. **Sree Ghitra Tirunal Institute for Medical Science and Technology, Thiruvananthapuram:** For developing biomedical engineering and technology or providing and also demonstrating high standards of patient care in advanced medical specialities.
4. **Indian Association for the Cultivation of Sciences, Kolkata:** It studies solid state physics, material sciences and chemistry, including biological chemistry, polymer science, theoretical physics, spectroscopy, energy research, etc.
5. **Indian Institute of Astrophysics, Bengaluru:** Research in emerging as well as interdisciplinary areas of astrophysics and heavenly bodies and development of instruments used in astrophysical studies.
6. **Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru:** Research in frontier areas of chemistry, physics of materials, animal behaviour, genetics, and geodynamics condensed matter theory, etc.
7. **Raman Research Institute, Bengaluru:** Research in basic sciences such as astronomy, astrophysics, liquid crystals, etc.
8. **S.N. Bose National Centre for Basic Sciences, Kolkata:** Promotes advanced studies in selected branches of basic sciences.
9. **Birbal Shahni Institute of Paleobotany, Lucknow:** Research in the area of paleobotany and its relevance in modern context.
10. **Indian Institute of Geomagnetism, Mumbai:** Observing and understanding the physical processes in the innermost part of the earth.
11. **Wadia Institute of Himalayan Geology, Dehradun:** Basic research in areas of biostratigraphy, sedimentology, tectonics, petrology and geochemistry and environmental geology to understand the geodynamics of the Himalayan region.
12. **International Advanced Research Centre for Powder Metallurgy and New Materials, Hyderabad:** It involves in the development of high-performance materials and processes.
13. **Technology Information Forecasting and Assessment Council, New Delhi**
14. **Vigyan Prasar, Noida (U.P.)**
15. **National Accreditation Board for Testing and Calibration Laboratories, New Delhi**
16. **Centre for Liquid Crystal Research, Bengaluru**
17. **Aryabhatta Research Institute of Advanced Studies (ARIES), Nainital**
18. **Institute of Advanced Study in Science and Technology, Guwahati**
19. **National Innovation Foundation, Ahmedabad**

3.1 ENERGY

Over the last few years, India has achieved substantial synergy and momentum with the help of parallel integration of the administrative departments of coal, power and exhaustible energy. The national commitment goals set at **COP26 (2021) in Glasgow (Scotland) Convention by Hon'ble Prime Minister Sri Narendra Modi**, could possibly be achieved *via* dynamic policies and a vision aiming at sustainable development.

3.2 POWER MINISTRY

Indian government's **Ministry of Power** is empowered to supervise and assure adequate production of electricity which can sustain infrastructure development, on top of propagation and delivery. The ministry serves as a channel for communication among the various resources of electricity from central and state governments and also rural electrification projects are undertaken by it.

The power ministry got identity as a ministry, on 2 July 1992. The sectionalised parts of the ministry include the **Power Ministry**, the **Coal Ministry** and the **Ministry of New and Renewable Energy (MNRE).** The ministry launched the smart grid project in 2012.

3.3 COAL MINISTRY

The coal and lignite reserves including explorations, production, distribution, supply and even the pricing are under the surveillance of the Ministry of Coal through the government's **Coal India Limited** and its subsidiaries along with **Neyveli Lignite Corporation**.

3.4 MINISTRY OF NEW AND RENEWABLE ENERGY (MNRE)

Department of Non-conventional Energy Sources (DNES) was established in 1982 and became the Ministry of Non-traditional Energy Sources in 1992. The Ministry was re-christened as the **Ministry of New and Renewable Energy (MNRE)** in **October 2006**. Due to the fact that the concern related to country's energy security is growing, the role of new and renewable energy resources is assuming increasing significance recently.

COAL CONTROLLER'S ORGANISATION (CCO)

Ministry of Coal has one subordinate body 'the Coal Controller's Organisation' (CCO) which **collects and maintains coal production data** of all public and private sector coal mining in our country on a monthly basis. Its headquarters is at **Kolkata** with various field offices at Dhanbad, Ranchi, Bilaspur, Nagpur, Sambalpur, Kothagudem and Asansol.

Functions and Responsibilities of CCO

- It does **inspection** of collieries to ensure the quality with respect to grade or size of coal.
- It works as the **appellate authority** in case of any dispute rise between consumers and owner in respect of grade and size of coal.
- It also **regulates disposal** of coal stock.
- It **provides grant** for opening or re-opening permission of any coal mine.
- It does the **assessment and collection of excise duty** levied on all raw coal and its dispatch.
- It also **submits monthly coal data** to various central and state government's ministries.

3.5 INDIAN RENEWABLE ENERGY DEVELOPMENT AGENCY (IREDA)

India established Renewable Energy Development Agency (IREDA) in 1987 as a **public-sector nonbanking company** under MNRE with the primary goal of **providing loans** for new and renewable sources of energy, thereby **promoting project viability**. Additionally, to promote participation of new entrepreneurs, IREDA has started entrepreneur development programme, providing training and assistance to new entrepreneurs in this field. The major objectives of IREDA are:

1. **Financial support** to certain projects and schemes related to energy and electricity production with the help of renewable and latest sources, enhancing efficiency of energy.
2. **Betterment in efficiency** through periodical improvement systems, processes and resources, and subsequently assuring consumer satisfaction in addition to the share of IREDA in the sector of renewable energy through innovation.

3.6 NON-RENEWABLE AND RENEWABLE SOURCES OF ENERGY

Renewable sources of energy are the energy sources, which are naturally refilled on a human timescale,

and can be used many times due to its inexhaustible property. Examples include sunlight, wind, rain, tides, waves and geothermal heat, etc. Non-renewable source of energy is a resource that does not revive itself at a sufficient rate, being exhaustible in nature. Most of the fossil fuels like coal, petroleum and natural gas are examples of non-renewable sources. While non-renewable resources are considered to be polluting agents due to the release of carbon dioxide, nitrogen oxides, sulphur oxides, methane and carbon monoxide; renewable sources are considered to be clean sources of energy, as no pollutant is emitted upon harvesting these resources. Over all, grid installed capacity from all sources are given in Table 3.1.

STUDY OF FUEL ON THE BASIS OF CALORIFIC VALUE

Calorific value of a fuel is the amount of heat evolved, in kilojoules, when one gram of the fuel is burned completely to form carbon dioxide and water. Its unit is kilojoule per gram (kJ/g). Higher calorific value of fuel means better quality of fuel. Hydrogen has the highest calorific value among all fuels.

Fuel	Calorific Value (kJ/g)
Coal	30
Petrol	48
LPG	50
CNG	55
Hydrogen	150

THE PETROLEUM AND NATURAL GAS REGULATORY BOARD ACT, 2006 (PGNRB ACT, 2006)

PGNRB was constituted in 2006. This Act provides Petroleum and Natural Gas Regulatory Board to **regulate the refining, processing, storage, transportation, distribution, marketing and sale of petroleum, petroleum products and natural gas excluding production** of crude oil and natural gas so as to protect the interests of consumers and entities engaged in specified activities relating to petroleum, petroleum products and natural gas and to ensure uninterrupted and adequate supply of petroleum, petroleum products and natural gas in all parts of the country and to promote competitive markets and for matters connected therewith or incidental thereto. This clearly indicates that it ensures a competitive market for gas. An Appellate Tribunal established under section 110 of the Electricity Act, 2003 (36 of 2003) shall be the Appellate Tribunal for PGNRB.

TABLE 3.1 Grid-connected, Total Including Non-renewable and Renewable Sources

Total Installed Capacity (As on 30 April 2023)

(A) Installed Generation Capacity (Sector-Wise)

Sector	MW	% of Share in Total
Central Sector	1,00,055	24.0%
State Sector	1,05,726	25.4%
Private Sector	2,10,810	50.6%
Total	4,16,591	100%

(B) Installed Generation Capacity (Fuel-Wise)

Category	Installed Generation Capacity (MW)	% of Share in Total
(i) Fossil Fuel		
Coal	205,235	49.3%
Lignite	6,620	1.6%
Gas	24,824	6.0%
Diesel	589	0.1%
Total Fossil Fuel	**2,37,268**	**57.0%**
(ii) Non-Fossil Fuel		
Renewable Energy Sources (Including Hydro)	172,542	41.4%
Hydro	**46,850**	11.2%
Wind, Solar & Other RE	125,692	30.2%
Wind	42,868	10.3%
Solar	67,078	16.1%
BM Power/Cogen	10,248	2.5%
Waste to Energy	554	0.1%
Small Hydro Power	4,944	1.2%
Nuclear	6,780	1.6%
Total Non-Fossil Fuel	**179,322**	43.0%
Total Installed Capacity (Fossil Fuel & Non-Fossil Fuel)	**4,16,591**	**100%**

[*Source:* Central Electricity Authority (CEA)]

3.6.1 Non-Renewable Sources

3.6.1.1 Coal (Solid Nature of Fuel)

3.6.1.1.1 Coal

One of the oldest forms of energy known to mankind is coal-based energy. India majorly depends on coal to meet its energy requirements, i.e., around 55–60%. There

are four types of coal found in India. The classification is on the basis of content of carbon in the coal. These are:

1. **Anthracite:** The best quality of coal with **85% carbon.** Anthracite is a very hard, compact, jet black coal with semi-metallic sheen.
2. **Bituminous:** The most widely used coal is bituminous with **50–85% carbon,** which is dense, compact and brickle and is usually black in colour. Since it has a high proportion of carbon and low moisture content, its calorific value is remarkable. Jharkhand, Odisha, West Bengal, Chhattisgarh and Madhya Pradesh have high deposits of this type of coal.
3. **Lignite:** It is a lower grade coal, containing about **35–50% carbon,** and it is commonly known as brown coal. It hails to the intermediate stage during the alternation of wood matter into coal. Its colour varies from dark black to brown. The major lignite reserves are in Palna of Rajasthan, Neyveli of Tamil Nadu, Lakhimpur of Assam and Karewa of Jammu and Kashmir.
4. **Peat:** The first stage of transformation of wood into coal results in peat containing **less than 35% carbon.** It is sometimes sufficiently compact to be used as a good fuel without constricting into bricks. With no support, it burns like wood, giving less heat and fuming more smoke and leaving behind a lot of ash.

COAL MINES (NATIONALISATION) ACT, 1973

India's coal industry was predominantly driven by the private sector after Independence until the Indira Gandhi government decided to transfer all coal holdings to Coal India through the **Coal Mines (Nationalisation) Act, 1973.** India's coal blocks are allocated on an auction basis. India is still not self-sufficient in coal production to fulfil basic need for power generation.

India is among the top five leading producer of coal of the world. China tops the list, followed by United States and Australia. India ranks fourth. Around 70% of the coal production comes from four eastern states of Chhattisgarh, Jharkhand, Odisha and West Bengal. Other leading producer are Andhra Pradesh, Madhya Pradesh and Maharashtra. Indian coal has high ash content but the amount of sulphur content is very low. **Burning of coal (Thermal Power Plant) generates various pollutants in air like CO_2, SO_2, NO_x, etc. Mercury is also released into the air from the combustion of coal.** Some of the areas in India have used sea water at coal-based thermal power plants for its cooling. Approximately 40% of India's thermal power plants are in water scarce areas. In India, Adani Power Limited is the largest private thermal power producers with installed capacity of 13650 MW (2023).

COAL ASH: HAZARDOUS TO HUMAN HEALTH

Coal ash is the waste that is left after combustion of coal. It includes fly ash (fine powdery particles that are carried up the smoke stack and captured by pollution control devices) as well as coarser materials that fall to the bottom of the furnace. Most coal ash comes from coal-fired electric power plants.

- Coal ash typically contains heavy metals including **arsenic, lead, mercury, cadmium, chromium** and **selenium**, as well as **aluminium, antimony, barium, beryllium, boron, chlorine, cobalt, manganese, molybdenum, nickel, thallium, vanadium** and **zinc.**
- **Environmental Protection Agency (EPA)** has found that living next to a coal ash disposal site can increase one's risk of cancer or other diseases.
- If one lives near an unlined wet ash pond (surface impoundment) and gets daily drinking water from a well, **he may have as much as 1 in 50 chance of getting cancer from drinking arsenic-contaminated water.**
- If eaten, drunk or inhaled, these toxicants can cause cancer and nervous system impacts such as cognitive deficits, developmental delays and behavioural problems. They can also cause heart damage, lung disease, respiratory distress, kidney disease, reproductive problems, gastrointestinal illness, birth defects and impaired bone growth in children.
- The EPA estimates that 140 million tons of coal ash are generated annually.
- **Arsenic is one of the most common, and most dangerous, pollutants from coal ash.**
- The EPA also found that living near ash ponds increases the risk of damage from cadmium, lead and other toxic metals.
- Coal ash recycling poses health risks, especially where the ash is exposed to water: for example, when sprinkled as cinders on snowy roads, spread as agricultural fertilizer, or used as a landfill or to fill abandoned mines. All these uses pose threat to ground water or surface water.

3.6.1.1.2 *Fly ash from Coal-Based Power Plants*

Fly ash is obtained from the combustion process of coal, and is similar to the ash of a volcano. During the burning of coal in modern electricity generating plants, combustion temperatures reach 2800°F approximately. The non-combustible materials form two types of ashes, namely: bottom ash and fly ash. The light-weight sum of material that falls to the bottom of the boiler and aggregates is called bottom ash. While fly ash is the material that is blown up with the flue gases, where it gets collected and can be stored in silos for testing and other benefits.

Significance and Concerns Associated with Fly ash

- The order is significant because of the high contribution of fly ash to air and water pollution and its impact on crops being grown in villages around these plants.
- Fly ash is a major source of PM 2.5 (fine, respirable pollution particles) in summer. It becomes air borne, and gets transported to a radius of 10 to 20 km. It can settle on water and other surfaces. Fly ash contains heavy metals from coal, a large amount of PM 2.5 and black carbon (BC). Proper disposal of fly ash is still not happening in many places.

What can be done?

- Fly ash, the end product of combustion during the process of power generation in the coal-based thermal power plants, is a proven resource material for many applications of construction industries and currently is being utilised in manufacturing of Portland Cement, bricks/blocks/tiles, road embankment construction and low lying area development, etc.

COMPOSITION OF FLY ASH

It is a coal combustion product and popularly known as **flue ash or pulverised fuel ash.**

- **Made up of particulates that are driven out of coal-fired boilers together with the flue gases.**
- The components of fly ash vary considerably depending upon the source and composition of the coal being burned, but **all fly ash includes substantial amounts of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.**
- **Minor constituents include:** arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium and vanadium, along with very small concentrations of dioxins and PAH compounds. It also has unburnt carbon.

Health and Environmental Hazards of Fly ash

- **Toxic heavy metals present:** All the heavy metals found in fly ash – nickel, cadmium, arsenic, chromium, lead, etc. – are toxic in nature. They are minute, poisonous particles which accumulate in the respiratory tract, and cause gradual poisoning.
- **Radiation:** For an equal amount of electricity generated, fly ash contains a hundred times more radiation than nuclear waste secured via dry cask or water storage.
- **Water pollution:** The breaching of ash dykes and consequent ash spills occur frequently in India, polluting a large number of water bodies.
- **Effects on environment:** The destruction of mangroves, drastic reduction in crop yields, and the pollution of groundwater in the Rann of Kutch from the ash sludge of adjoining coal power plants has been well documented.

Application of Fly ash

- Concrete production, as a substitute material for Portland cement, sand.
- Fly ash pellets which can replace normal aggregate in concrete mixture.
- Embankments and other structural fills.
- Cement clinker production – (as a substitute material for clay).
- Stabilisation of soft soils.
- Road subbase construction.
- As aggregate substitute material (e.g. for brick production).
- Agricultural uses: soil amendment, fertiliser, cattle feeders, soil stabilisation in stock feed yards, and agricultural stakes.
- Loose application on rivers to melt ice.
- Loose application on roads and parking lots for ice control.

- At present, 63% of the fly ash is being utilised and target is for 100% utilisation of the fly ash. There is need for education and awareness generation.
- Road contractors and construction engineers need to know the benefits of using fly ash in construction.
- Measures need to be taken to reduce the cost of construction of roads using fly ash by way of tax structure, subsidies and transportation services.
- Besides, there is a need to prevent the ash from coming to the power plant by washing the coal at its place of origin. The government should also come out with a policy to encourage fly ash use in cement plant.

Note: Environmental Protection Agency (EPA) also reported that fly ash is not good for human health.

3.6.1.1.3 Coal Gasification and Liquefaction

(A) Gasification

It is **the process of converting any carbon-based raw material such as coal into fuel gas popularly known as syngas.**

The coal is fed into a high-temperature pressurised container (gasifier) and combined with hot steam and controlled amounts of air or oxygen under high temperatures (up to 2600°F) and high pressures (up to 1200 psig) to generate synthetic gas or 'syngas'. Typically syngas is a mixture of carbon dioxide, hydrogen, methane, and nitrogen and carbon monoxide.

Benefits of Gasification

Transporting gas is a lot cheaper than transporting coal.

1. Syngas burns much **cleaner** and **reduces air pollution**; it is renewable and does not depend on fossil fuels.
2. It has **greater efficiency** than conventional coal-burning because it can effectively use the gases twice: the coal gases are first cleansed of impurities and fired in a turbine to generate electricity. The exhaust heat from the gas turbine can be captured and used to generate steam for a steam turbine generator.

Concerns and Challenges

- Coal gasification is one of the **more water intensive forms of energy production.**
- Also, there are concerns about water contamination, land subsidence and disposing of waste water safely.

(B) Liquefaction

It is also called **Coal to Liquid (CTL) technology.** It is **an alternative route to produce diesel and gasoline** and makes economic sense only in a world of high crude oil prices.

- The **process involves** gasification of coal, which in turn will produce synthetic gas (a mix of $CO+H_2$). The synthetic gas can be liquefied to its fuel equivalent in presence of cobalt/iron-based catalysts at higher pressure and temperature.
- However, liquefied coal emits twice as much CO_2 as burning oil. It also emits a large volume of SO_2.

Benefits of Liquefaction

The CO_2 emissions are more readily and cheaply captured from CTL plants than from conventional coal-fired power stations. The captured CO_2 can be transported and injected into underground storage reservoirs (a procedure known as 'carbon capture and storage' (CCS) or 'geosequestration').

Union Minister of Coal and Mines made a target on Coal Gasification and Liquefaction in coming future:

- India aims for 100 million tonnes (MT) coal gasification by 2030 with investments worth over ₹4 lakh crores.
- For encouraging use of clean sources of fuel, government has provided for a concession of 20% on revenue share of coal used for gasification. This will boost production of **synthetic natural gas, energy fuel, urea for fertilisers** and **production of other chemicals.**

HIGH VOLTAGE DIRECT CURRENT (HVDC)

The transmission modes and wires we use for electricity transmission have more than 40% losses.

It is a highly effective mode for electricity transmission in long-range distribution to minimise transmission losses. Here, transmission mode of electricity is Direct Current (DC) in high voltage. This type of technology will be introduced in coming future.

3.6.1.2 Petroleum (Liquid Nature of Fuel)

3.6.1.2.1 Differences Among Different Natures of Fuel

A 'crude oil', which is pumped out of the ground, is a black liquid. The constituents of this liquid are aliphatic hydrocarbons, or hydrocarbons composed of hydrogen and carbon, wherein the carbon atoms link together in chains of varying lengths.

Different lengths of hydrocarbons have different properties and behaviours. For instance, one carbon atom chain is the lightest chain, known as methane (CH_4). Longer the chain, heavier is the hydrocarbon. The first four chains of hydrocarbons – CH_4 (methane), C_2H_6 (ethane), C_3H_8 (propane) and C_4H_{10} (butane) – are all gases. The chains up to $C_{18}H_{32}$ or so are all liquids at room temperature, while heavier chains above C_{19} are all solids at room temperature.

3.6.1.2.2 Premium Fuels: Fact versus Fiction

- **Research Octane Number (RON)** is a standard measure of the performance of a gasoline engine fuel.
- Fuels with a higher RON are mostly used in high-performance engines that have higher compression ratios.
- In India, most of the ordinary and premium petrol are 91 RON. The premium petrol is generally ordinary petrol with additives; hence they don't really change the value of RON.
- However, in some places, two variants – 93 Octane and 97 Octane – are also available with RON values of 93 and 97, respectively.
- In January 2017, 99 Octane was launched having RON 99 and it is the most advanced automotive fuel for sale in India till date.
- **Compression Ratio (CR)** is simply the ratio of the volume inside the cylinder of an engine, before and after compression. Therefore, a compression ratio of 10:1 means that an engine can compress the air and fuel mixture 10 times to that of the initial volume.
- Generally, with a higher compression ratio, you need a higher grade fuel to withstand the extreme pressures generated in the engine as a result. A higher grade fuel in this aspect means a fuel with a higher value of RON. A majority of the petrol engines have a compression ratio between 8:1 and 12:1. However, racing cars and bikes are exceptions, as they operate at very high CRs like 13:1 or even higher (**Table 3.2**).
- In a normal petrol engine, the air fuel mixture is heated due to being compressed and then is ignited rapidly by the spark plug. If this mixture is heated (or compressed) too much, it will self-ignite before the ignition system sparks. This will lead to much higher stresses than what the engine components are designed for, and can cause a **'knocking'** or **'pinging'** sound.
- Knocking can cause major engine damage or even seizures, if severe. The compression ratio is directly related to power and efficiency of an engine.
- Therefore, engines with higher compression ratios can extract more energy from the same quantity of fuel as compared to engines with lower compression ratios.
- Sports cars and bikes have engines that are designed to operate at a compression, and thus demand fuels of higher RON.

TABLE 3.2 High versus Low Compression Ratio

Higher Compression Ratio	Lower Compression Ratio
Increased power output	Lower power output
Improved mileage	Reduced mileage
Slightly shorter engine life	Slightly longer engine life
Requires high octane fuel	Requires normal fuel
Risk of engine knocking	Negligible risk of engine knock

Benefits of High Octane Fuel

- Increased power output
- Improved fuel efficiency
- Lesser engine maintenance
- Better engine life

3.6.1.2.3 Asphalt and Bioasphalt

Asphalt is brown/black, highly viscous hydrocarbon produced in the residue of petroleum distillation. This distillation process occurs naturally in asphalt lakes or under petroleum refinery by using crude oil.

Bioasphalt is an alternative of asphalt, made from non-petroleum-based renewable resources. These sources include sugar, molasses, rice, corn, potato, starch, gum, resins, latex, vegetable oil, cellulose, lignin, dried sewage effluents, etc. Bioasphalt is eco-friendly and is also used in road construction.

Asphalt is highly used in road construction, where it is used as the **glue or binder mixed** with aggregate particles to create asphalt concrete. Its other main uses are for bituminous waterproofing products, including production of roofing felt and for sealing flat roofs.

TERMINOLOGY

Knocking and Anti-knocking Agent

Some fuels, when burnt, produce heat but this heat of the fuels does not transform into exact work and produces metallic sound, which is called knocking. Thus, those fuels, whose knocking is very low, are assumed the best fuels and vice-versa. To lower knocking, some compounds are added in the fuel to make the fuel good and such compounds are called anti-knocking compounds. The best anti-knocking compound is **Tetra Ethyl Lead (TEL).** Another ace anti-knocking compound is **Benzene Toluene Xylene (BTX)** and some other anti-knocking compounds are **Methanol** or **Ethanol, Alcohol** and **Tertiary Butyl Alcohol.** However, TEL is harmful for environment.

Octane Number

The knocking of fuel is expressed by octane number. Octane number is high for low knocking, so fuel is good and vice-versa. Thus, for increasing the octane number of the fuels, anti-knocking compound is necessarily mixed up.

Note: The increase in the carbon chain length leads to decrease in the Octane number.

Gasohol

It was firstly discovered in Brazil. The mixture of petrol (80–90%) and alcohol (10%) is called gasohol, and it is obtained by mixing petrol in extracted alcohol of sugarcane. By the use of gasohol as a fuel in the vehicles, pollutants like CO_2, SO_2, etc., can be reduced and minimised up to an extremely lower level. Thus, gasohol can be a better alternative option of the petrol because of great demand of petrol.

Diesel

This is a type of oily liquid hydrocarbon obtained by the fractional distillation of petroleum. This is cheaper than petrol and a good fuel used in vehicles, machines, devices, etc. But during its consumption, various toxic gases like sulphur dioxide (SO_2), etc., are evolved. **The gas SO_2 creates some problems like irritation in eyes, headache, inhaling problems, etc., and sometimes skin diseases and respiratory system problems also come into existence.**

Ultra Low Sulphur Diesel (ULSD) or City Diesel

This is an extremely pure form of diesel. Through the combustion of this diesel, less pollutants are spread in the atmosphere because of low sulphur presence in it. It is used frequently in almost all cities of Europe.

Cetane Number of Diesel

Cetane number or CN is an indicator of the combustion speed of diesel fuel. The higher the Cetane number, the more easily the fuel will combust in a compression setting (such as a diesel engine).

Notes: Additives alkyl nitrates (principally 2-ethylhexyl nitrate) and di-tert-butyl peroxide are used as additives to raise the cetane number.

3.6.1.3 Gaseous Nature of Fuel

As suggested by the name, natural gas is a gaseous fuel which contains 87–92% of methane and a small percentage of other higher hydrocarbons. The different forms of gases under varied temperature and pressure include LPG, PNG, CNG and LNG.

Problem with Gaseous Nature of Fuel

Gaseous nature of fuel has maximum calorific value but still has many problems:

- Their **ignition temperature** (minimum temperature at which a fuel catches fire) is normal room temperature.
- They are **odourless.**
- **Maximum chances of friction,** if not properly packed or processed.

3.6.1.3.1 LPG, PNG, CNG and LNG

The by-product of natural gas processing and petroleum refining is LPG. The components of LPG are gases at normal temperatures and pressures. Liquefied Petroleum Gas or LPG (also known as Auto gas) consists mostly of propane, propylene, butane and butylene in different mixtures. LPG is odourless and can burn at room temperature and hence, **Ethyl Mercapton** is added to it for smell, so as to identify its leakages *via* smell. Due to widely varied composition, LPG gives variable engine performance and cold starting performance, and this is seen as one limitation of LPG. At normal temperatures and pressures, LPG will evaporate, thus arises the need to store it in pressurised steel bottles.

Natural gas consists mainly of methane and is drawn from gas wells or in conjunction with crude oil production. Other constituents may include hydrocarbons such as ethane and propane as well as other gases such as nitrogen, helium, carbon dioxide, sulphur compounds and water vapour. Compressed Natural Gas or CNG is stored in high-pressure tanks – 20–25 mega Pascal (200–250 bar) on the vehicle. **For detection of leakage, sulphur-based odour is normally added to CNG.** As compared to gasoline, natural gas is effective in terms of safety as it is lighter than air and will normally disperse in case of leak.

A natural gas stored as a super-cooled (cryogenic) liquid is termed as **Liquefied Natural Gas or LNG.** To distil natural gas, the required temperature depends on its precise composition; however, it is typically between –120 and –170°C (–184 and –274°F). LNG is advantageous due to energy density offered, which is comparable to petrol and diesel fuels, extending range and reducing refuelling frequency.

However, the high cost of cryogenic storage on vehicles and the major infrastructure requirement of LNG dispensing stations, production plants and transportation facilities count towards its disadvantages. Currently, heavy-duty applications in places like the United States, Japan, the United Kingdom and some countries in Europe are using LNG. However, being a less cost-effective option, this is currently not a practical option for many developing nations.

HYDROGEN-ENRICHED CNG (HCNG)

HCNG is a mixture of compressed natural gas (CNG) and some percentage of Hydrogen for heat or energy generation. HCNG which may be used as a fuel of Internal Combustion Engine (ICE) is considered a cleaner source of fuel, more powerful and offers more mileage than even CNG.

Some Advantages of HCNG

- HCNG reduces emissions of CO up to 70%.
- Enables up to 5% savings in fuel.
- Better performance due to higher Octane number.

In 2018, **Delhi Government** has tied up with **Indian Oil Corporation Limited (IOCL)** to study the technology and infrastructure needs to induct 50 HCNG buses on a trial basis. IOCL has plans to mix (18–20%) Hydrogen in these buses. Current cost of H_2 is more than the cost of Natural Gas. So, HCNG is costlier than CNG.

LNG Terminals in India

- RGPPL LNG Terminal, Maharashtra
- Dahej Terminal, Petronet LNG Ltd., Gujarat
- Hazira Terminal, Shell Ltd., Gujarat
- Petronet LNG, Kochi
- Krishna Godavari LNG import terminal at Kakinada

PNG (Pipelined Natural Gas) is similar to CNG, except that, it is supplied through pipelines for household use.

PROCESSING OF NATURAL GAS

LPG fractionator plants are used to process natural gas to dissipate it into different fractions as per different applications.

- **Methane** – Fuel and feedstock for urea plants and fuel for power plants
- **Ethane** – Production of petrochemicals
- **Propane** – LPG and industrial fuel
- **Butane** – Production of LPG
- **C5 and heavier** – Production of solvents and pentane

3.6.1.3.3 Unconventional Gas Sources

The production of these gas resources needs greater effort than other resources and these gas resources exist in the reservoirs. These resources require technology of specialised form, which is totally dependent on their nature of specific situation presence. Conventionally, the following gas sources are classified as unconventional sources: **Coal mine methane, Shale gas, Coal bed methane, Tight gas** (Tight gas is natural gas which is produced from reservoir rocks with so low permeability that massive hydraulic fracturing is necessary to produce the well at economic rates). However, the global demand of gas, which is expected to rise by 50% from 2010 to 2035, is likely to come from unconventional sources.

3.6.1.3.3.1 Coal Bed Methane (CBM)

It is an unconventional form of natural gas found in coal deposits or coal seams. CMB is formed during the process of coalification, the transformation of plant material into coal.

CBM Potential

- India has the **fifth-largest coal reserves** in the world, and CBM has been looked at as a clean alternative fuel with significant prospects.

- India's CBM resources are estimated at around 92 trillion cubic feet (TCF), or 2,600 billion cubic metres (BCM).
- The country's coal and CBM reserves are found in 12 states of India, with the Gondwana sediments of eastern India holding the bulk.
- The Damodar Koel valley and Son valley are prospective areas for CBM development.

Note: Ministry of Coal has asked the state-run coal miner Coal India Limited (CIL) to produce 2 MMSCB (million metric standard cubic metres) per day of coal bed methane (CBM) gas in the next 2–3 years.

Use of CBM

- In power generation.
- As compressed natural gas (CNG) auto fuel.
- As feedstock for fertilisers.
- Industrial uses such as in cement production, rolling mills, steel plants and for methanol production.

Advantages

- High calorific value.
- Contains 95% pure methane and is hence a good fuel.
- Does not contain harmful gases like H_2S.
- Environment friendly when compared with other conventional sources of energy.

Disadvantages

- Methane, being a greenhouse gas, becomes a matter of concern, keeping in view the emissions from coal mines (accounts approximately 8% of total global methane emission).
- Drilling of land for the extraction of CBM results in acute ecosystem damage.
- Wild life habitats are disturbed.
- Extraction of CBM involves disposal of highly salinized water, whose introduction to fresh water ecosystem poses a serious threat to the aquatic environment.
- Correct stimulation of gas content, thickness, reservoir pressure is a bit difficult.

3.6.1.3.3.2 Gobardhan Scheme

The **Galvanising Organic Bio-Agro Resources Dhan (GOBAR-DHAN) scheme** is implemented under **the Swachh Bharat Mission Gramin-Phase 2,** by the Department of Drinking Water and Sanitation under the Jal Shakti Ministry.

About the Scheme

- It was **launched in 2018.**
- The scheme aims to augment income of farmers by **converting biodegradable waste into compressed biogas (CBG).**
- The initiative aims at attracting entrepreneurs for establishing community-based CBG plants in rural areas.
- **The Ministry of Jal Shakti** has launched a unified portal on the government's **'Gobardhan' scheme.** Farmers can earn ₹1 lakh crore in 5 years from Jal Shakti Ministry's Gobardhan scheme, says Government.

Benefits of the Scheme

1. Helpful for the country as India is home to the highest cattle population in the world, close to 300 million in number, with a daily output of 3 million tonnes of dung.
2. Encourage farmers to consider dung and other waste not just as a waste but as a source of income.
3. Benefits to the rural people. It will be easier to keep the village clean and sanitised, livestock health will improve and farm yields will increase.
4. Increase self-reliance in energy utilised for cooking and lighting.
5. Provide a stable fuel supply in the market for oil companies and accessible credit in the market through government schemes and banks for entrepreneurs.

(Refer **Infographic – Biogas Cycle**)

3.6.1.3.3.3 Gas Hydrates/Clathrates/Methane Hydrates

Gas hydrates are naturally occurring ice-like combination of natural gas and water, firstly found in polar regions. Basically, these are solids, made up of hydrocarbon gas (mainly Methane) and liquid water. They resemble wet snow and can exist at temperatures above the freezing point of water. With pressurisation, they remain stable at temperatures up to 18°C. Hydrates belong to a form of complexes known as Clathrates. Clathrates are substances having a lattice-like structure, in which molecules of one substance are completely enclosed within crystal structure of another.

Hydrates are generally present in oceanic sediments (under the seafloor) along continental margins and in polar continental settings (Arctic tundra, etc.). Gas hydrates are restricted to shallow lithosphere (2000–4000 metre depth). Studies show that **gas hydrates found mainly in ocean bed (around 98%) and 2% on land**. Gas hydrate regions in India include **Western, Eastern and Andaman offshore areas, Krishna Godavari basin, Mahanadi basin** and **shallow areas of Bay of Bengal**.

3.6.1.3.3.4 Shale Gas

Shale formations contain a natural gas trapped, known as Shale gas. Fine-grained sedimentary rocks, which are rich resources of petroleum and natural gas are shale. **Horizontal drilling** on **combining with hydraulic fracturing**, over the past decade has enabled access to large quantity of shale gas that were previously not lucrative to produce. The **hydraulic fracturing (fracking)** technology's latest advancements cropped up shale gas boom in recent years for creation of extensive artificial fractures around the well bores.

Since the start of this century, shale gas has rapidly emerged as an important source of natural gas in the United States, and this attracted efforts to seek potential shale gas in the other parts of the world. The progression is so rapid that, in 2000, shale gas provided only 1% of US natural gas production; and within a span of a decade, that is by 2010, it went over 20%. Currently, the US government's Energy Information Administration predicts that **by 2035, 46% of the United States' natural gas supply will come from shale gas**.

Shale Gas in India

'Shale Gas in India: Look Before You Leap' – The latest policy brief raises the question of the role of shale gas as the game changer in Indian context. Coal bed methane or CBM (sometimes called sweet gas) is taken out from coal beds and differs from shale gas. The export of guar gum from India (India being the largest producer of Guar), which serves in improving the resistance of a liquid and flow of water in the frocking process of unconventional gas and, in terms of depth, occurs much closer to the land surface than other similar gases, marks another interesting contribution to shale gas development in the United States.

Six basins are identified as potentially shale gas bearing, by the **Ministry of Petroleum and Natural Gas (MoPNG)**, which include **Cambay, Assam-Arakan, Gondwana, Krishna–Godavari, Kaveri and the Indo-Gangetic plain.** In 2012, a draft policy for the exploration and exploitation of shale gas, calling for suggestions from the general public, stakeholders, environmentalists, etc., was also put by India. To exploit shale gas/oil at optimum level requires horizontal and multilateral wells and multistage hydraulic fracturing treatments to stimulate oil and gas production from shale. A huge amount of water, around 3–4 million gallons per well (11,000 to 15,000 cubic metres of water required for drilling/hydro fracturing bearing upon the well type and shale characteristics), is required for this purpose. Unfortunately, India has been facing physical and economic water paucity while the United States and Europe have no such worries for water. Country-wise data of Shale gas reserves are given in **Table 3.3**.

TABLE 3.3 Leading Countries with Technically Recoverable Shale Gas Resources

Rank	Country	Technically Recoverable Shale Gas (Trillion Cubic Feet)
1	China	1,115
2	Argentina	802
3	Algeria	707
4	United States	623
5	Canada	573
6	Mexico	545
7	Australia	429
8	South Africa	390
9	Russia	285
10	Brazil	245
11	India	96
	World Total	7,576

The situation for India may be worsened in the next 12–15 years, when the consumption of water is expected to increase by over 50%, against which the supply will increase by only 5–10%. Because of the large area required for fracking, the issue of land acquisition and consequent displacement of people will surely bother, though currently, it is not a part of the policy. While the potential conventional gas is overshadowed by that of shale gas reserves, we have a long way to cover in terms of identifying shale gas-rich basins and

acquiring the necessary technology and experience for extraction of shale gas. The shale has low permeability and hence greatly inhibits the gas from migrating to more permeable reservoir rocks. Shale gas production would be economically unrealistic without horizontal drilling and hydraulic fracturing. To justify the cost of drilling, the natural gas would not flow from the formation at high enough rates. Since the availability of fresh drinking water is decreasing year by year due to dropping of groundwater levels, and the increasingly polluted rivers and other water bodies, the water solution will only get worse and will not improve.

Advantages

- Greenhouse gas emission from shale gas is less.
- More environmental friendly than coal.
- Cost effective.
- Electricity generation from shale gas is cheaper than coal.
- Shale gas is a less-intensive carbon fuel than other fossil fuel.

Guar Beans and its Uses

Guar beans (cluster beans) have been cultivated in north-enwestern India and Pakistan for at least several centuries. It is an **annual legume** that grows well in a variety of soil types and in **arid to semi-arid climates**. Farmers take advantage of the **nitrogen-fixing abilities** of the guar plant by using it as a green manure crop. Guar gum is water soluble and is used in **recipes as a thickener**. It is very similar to corn starch.

It is used to thicken dairy products such as **milk, yoghurt, cheese, ice cream** and **sherbet**. In processed foods, guar gum is used as a thickener in **salad dressing, sauces, ketchup, soup** and many other products.

During 2012–14, Guar gum was in **high demand to use in hydraulic fracturing technology** for shale gas exploration.

Guar Gum Economics

Primarily, most of the world's supply of guar beans was used as food for animals and people with a small amount going to the food-processing industry. However, in the last few years, the use of guar gum in hydraulic fracturing began to increase rapidly.

Disadvantages

- Extraction process involves greenhouse gas emission (mainly methane), introduction of chemicals and wastes, environmental pollution and methane leakage.
- It produces photochemical smog.
- Extraction processes like hydraulic fracturing may contaminate the ground water aquifers with methane, which consequently affect the aquatic eco-system.
- Hydraulic fracturing process may trigger seismic activities. Pollution can also occur through reinjection wells.

(Refer **Infographic – Shale Gas**)

3.6.1.3.3.5 Hydrogen Fuel

(A) Importance of Hydrogen Fuel

Hydrogen is **the lightest and first element on the periodic table.** Since **the weight of hydrogen is less than air,** it rises in the atmosphere and is therefore **rarely found in its pure form, H_2.**

At standard temperature and pressure, hydrogen is a non-toxic, non-metallic, odourless, tasteless, colourless and highly combustible diatomic gas.

Hydrogen fuel is **a zero-emission fuel** burned with oxygen. It is alternative fuel that can be produced from diverse domestic resources such as natural gas, nuclear power, biomass and renewable power like solar and wind. Although the market for hydrogen as a transportation fuel is in its infancy, it **can be used in fuel cells or internal combustion engines.** It is also **used as a fuel for spacecraft propulsion.**

Occurrence of Hydrogen

- It is the most abundant element in our environment. The sun and other stars are composed largely of hydrogen.
- Astronomers estimate that 90% of the atoms in the universe are hydrogen atoms. Hydrogen is a component of more compounds than any other element.
- It is stored in water (H_2O), hydrocarbons (such as methane, CH_4) and other organic matter. One of the challenges of using hydrogen as a fuel comes from being able to efficiently extract it from these compounds.
- **Molecular hydrogen is not available on Earth in convenient natural reservoirs.**

Storage

Hydrogen is abundant in our environment. It is stored in water (H_2O), hydrocarbons (such as methane, CH_4) and other organic matter. One of the challenges

of using hydrogen as a fuel comes from being able to efficiently extract it from these compounds.

- Hydrogen **can be stored physically as either a gas or a liquid.**
- Storage of hydrogen as a gas typically requires high-pressure tanks.
- Storage of hydrogen as a liquid requires cryogenic temperatures because the boiling point of hydrogen at one atmosphere pressure is –252.8°C.
- Hydrogen can also be stored on the surfaces of solids (by adsorption) or within solids (by absorption).

Potential of Clean Hydrogen Industry in Reducing Greenhouse Gas Emissions

1. Hydrogen is a clean fuel that, when consumed in a fuel cell, produces only water.
2. Hydrogen is considered an alternative fuel. Efforts are underway by the government and industry towards clean, economical and safe hydrogen production and distribution for widespread use in **fuel cell electric vehicles (FCEVs)** as they are found to be more efficient than vehicles running on gasoline.
3. Light-duty FCEVs are now available in limited quantities to the consumer market in localised regions domestically and around the world.
4. The energy in 2.2 pounds (1 kilogram) of hydrogen gas contains about the same as the energy in 1 gallon (6.2 pounds, 2.8 kilograms) of gasoline.

GAIL Starts India's Maiden Project of Blending Hydrogen into Natural Gas System in Indore

- In line with **National Hydrogen Mission,** in 2022 GAIL commenced **India's first-of-its-kind project of mixing hydrogen into the natural gas system** to establish the techno-commercial feasibility of **blending hydrogen in City Gas Distribution (CGD) network.**
- The project got initiated in Indore, Madhya Pradesh.
- GAIL started injecting grey hydrogen. This grey hydrogen would subsequently be replaced by green hydrogen.
- The hydrogen-blended natural gas is being supplied to Avantika Gas Ltd, one of GAIL's joint venture with HPCL, for retailing of CNG to automobiles and piped natural gas to households in Indore.

The Goal

The government is planning **to blend 15% green hydrogen with piped natural gas (PNG)** for domestic, commercial and industrial consumption.

(B) National Hydrogen Mission (NHM)

Energy transition is underway at an exceptional level and several countries are betting on **hydrogen to emerge as the top clean fuel with its high energy density and versatility.** Government of India's (GOI) **National Hydrogen Energy Mission (NHM) initiative** will capitalise on this.

Efforts in this Regard

- In the Union Budget 2020–21, the Finance Minister formally announced the NHM, with the aim to generate hydrogen from green power resources.
- The National Green Hydrogen Mission was **approved** by the **Union Cabinet on 4 January 2022,** with the intended objectives of **'Making India a leading producer and supplier of Green Hydrogen in the world'.**

Challenges for India

1. One of the colossal challenges faced by the industry for using hydrogen commercially is the economic sustainability of extracting green or blue hydrogen.
2. The technology used in production and use of hydrogen like carbon capture and storage (CCS) and hydrogen fuel cell technology are at nascent stage and is expensive which in turn increases the cost of production of hydrogen.
3. The maintenance costs for fuel cells post-completion of a plant can be costly, like in South Korea.
4. The commercial usage of hydrogen as a fuel and in industries requires mammoth investment in R&D of such technology and infrastructure for production, storage, transportation and demand creation for hydrogen.

(C) Various Types of Hydrogen

Based on the process of production, hydrogen can be classified into **Green Hydrogen, Blue Hydrogen, Pink Hydrogen, Grey Hydrogen and Yellow Hydrogen.**

(Refer **Infographic – Green Hydrogen**)

Steps taken by Government to Emphasise Green Hydrogen

- Nirmala Sitharaman, the Finance Minister of India, in her budget speech 2021–22, announced the launch of the **Hydrogen Energy Mission** to produce **hydrogen from renewable sources. In the recent 2023 Budget, Sitharaman also announced an additional ₹19,700 crore towards the government's Green Hydrogen Mission to lower carbon intensity and reduce fossil fuel use. She also announced a five million tonne target for green hydrogen production by 2030.**
- Indian Oil Corporation has signed an agreement with Greenstat Norway for setting up a Centre of Excellence on Hydrogen (CoE-H) which will promote R&D projects for the production of green and blue hydrogen between Norwegian and Indian R&D institutions/universities.
- **Under the aegis of the Strategic Clean Energy Partnership (SCEP), India and the US recently have set up a task force to mobilise finance and speed up green energy development.**

Steps Taken by Private Sector

- **Reliance Industries Ltd (RIL)** is investing **₹75,000 crore** in its new business focussed on clean energy, which includes solar and green hydrogen.
- **Reliance Industries, Indian Oil, NTPC, Adani Enterprises, JSW Energy and Acme Solar are all in the green hydrogen game, with the Adani Group having a tie-up with France.**

3.6.2 Renewable Sources of Energy

The energy that is collected from resources, which are naturally replenished on a human timescale, is termed as renewable sources of energy. They include sunlight, wind, rain, tides, waves and geothermal heat. The four important areas often supported by renewable energy are electricity generation, air and water heating/cooling, transportation and rural (off-grid) energy services.

Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy (MNRE). **The Union Finance Minister Nirmala Sitharaman on 1 February, 2023 allocated ₹10,222 crore toward the renewable energy sector in the Union Budget 2023.**

Advantages and Disadvantages of Renewable Energy

Advantages

- **Renewable Energy:** These sources are with infinite sustainability and we will never run out of it.
- **Environmental Benefits:** They are clean sources, causing little-to-no greenhouse gases and net carbon emissions, thus being eco-friendly.
- **Reliable energy source.**
- **Economic Benefits:** They are comparatively cheaper and more economically sound (being cost effective). As per estimations, renewable energy manufacturing will generate hundreds of thousands of stable jobs.
- **Stabilise Energy Prices:** They provide reliable pricing on energy.

Disadvantages

- **Reliability of Supply:** One flaw is that sources heavily depend upon the weather for sources of supply: For instance, rain, wind and sunshine. Climatic factors may also cause issues.
- **Difficult to Generate in Large Quantity.**
- **Large Capital Cost:** Initial investments are quite high to establish renewable energy plants.
- **Large Tracts of Land Required:** The electricity requirement is high and to replace the non-renewable source to fulfil such high demand, more and more solar panels and wind farms need to be set up, which require large tracts of land.

3.6.2.1 Various Renewable Energy Sources in India

3.6.2.1.1 Solar Energy

Due to the location of India between the Tropic of Cancer and the Equator, the average annual temperatures range around 25–27°C, which shows India's huge solar potential. India is one of the few countries with plenty of sunshine, with approximately 300 clear sunny days per year. 0.1% of the solar energy coming to Earth, which can be utilised in different ways.

3.6.2.1.1.1 Different Ways of Solar Energy Utilisation

There are different ways of solar energy utilisation:

1. Photosynthesis
2. Solar energy into thermal energy
3. Photovoltaic cells (solar energy into electrical energy)

Photosynthesis is a process through which plants use sunlight for food synthesis. Main source of life on Earth is the Sun due to autotrophic nature of plant.

Solar Energy into Thermal Energy This is a technology that will be used for the utilisation of solar energy for the generation of heat; e.g., **solar cooker, solar water heating system, solar air heating** and **solar pond.** Asia's first solar pond is located in Bhuj (Gujarat).

Concentrated Solar Thermal Systems (CSP) – The radiation of the sun is concentrated by CSP to heat a liquid substance, which is later used to drive a heat engine and even an electric generator. Alternating Current (AC) is generated by indirect method, which can be easily distributed on the power network.

Photovoltaic Cells (PVCs) Direct conversion of light into electricity, when light falls on certain elements like silicon the flow of electron starts. Photovoltaic (PV) solar panels, unlike solar thermal systems use sunlight through the 'photovoltaic effect' to generate direct current (DC) in a direct electricity production process rather than using the Sun's heat to generate power (as in solar thermal system). Here, the DC is then converted to AC, usually for which inverters are used, to be distributed on the power network.

Silicon wafer is a material essential for manufacturing of semiconductors, used in photovoltaic units. From last few years India has boost up manufacturing of silicon wafer in electronics. But India is not among top three manufacturing countries of silicon wafer.

(Refer Infographic – Solar Photovoltaic & Solar Water Heater)

(Refer Infographic – Mechanism of Solar Pond)

3.6.2.1.1.2 Solar Power Tariff

Solar energy based power generation in per unit price is solar tariff.

GREEN ENERGY CORRIDOR

The Cabinet Committee on Economic Affairs in 2022 approved **the scheme on Green Energy Corridor (GEC)** Phase-II for **Intra-State Transmission System (InSTS)**.

Green Energy Corridor Project for Intra-State Transmission System (InSTS)

- The **GEC Project** aims at synchronising electricity produced from renewable sources such as solar and wind with conventional power stations in the grid.
- The **GEC-InSTS** project was sanctioned in 2015–16, for evacuation and integration of the renewable energy capacity through setting up of transmission lines and increasing transformation capacity of substations.

Phase I of the Project

- **It is being implemented by eight renewable-rich states** of Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh and Madhya Pradesh.
- Under this phase, **the target is to** install 9700 circuit km of transmission lines and 22,600 MVA (MegaVolt-Amperes) transformation capacity of substations by 2022.
- The funding mechanism consists of a 40% Government of India Grant, 20% state equity and a 40% loan from KfW Bank, Germany.

Phase II of the Project

- It is being implemented in seven states namely, Gujarat, Himachal Pradesh, Karnataka, Kerala, Rajasthan, Tamil Nadu and Uttar Pradesh.
- Under this phase, the target is to install 10,750 circuit km of transmission lines and 27,500 MVA transformation capacity of substations by 2025–26.
- The Centre will provide assistance at 33% of the cost of the project.

Need for a Green Energy Corridor in India

- The Prime Minister has pledged **to increase the country's non-fossil fuel power generation capacity to 500 GW and meet 50% of its energy requirements from renewable sources** by the end of this decade. So there is a need for integration.
- The scheme will help in **achieving the target of 500 GW installed RE capacity by 2030**.
- It will also contribute to **long-term energy security of the country** and promote ecologically sustainable growth by reducing the carbon footprint.
- It will **generate large direct and indirect employment** opportunities for both skilled and unskilled personnel in power and other related sectors.
- The GEC will **help in offsetting the intra-state transmission charges** and keep the power costs down. Thus, the government support will ultimately benefit the end users.
- It helps India to increase the share of non-fossil fuels-based electricity to 40% by 2030.
- The project is expected to help India meet **the climate commitments it made at the COP26 summit in Glasgow.**

While the Central Electricity Regulatory Commission regulates the tariff of generating companies owned or controlled by the central government, the Solar Energy Corporation of India Limited (SECI) has a power trading license.

3.6.2.1.1.3 Ongrid and Offgrid System of Solar Power

(A) Ongrid

- Ongrid systems are solar PV systems that only generate power when the utility power grid is available. They must connect to the grid to function. They can send excess power generated back to the grid when you are overproducing, so you credit it for later use.
- This system is connected to the main power supply just like a regular home. This means that main power can still be used any time your solar panels generate less electricity than is needed.
- A solar electricity system without batteries is called grid-tied or grid-connected solar. It will enable

every home to be hooked up to both the national grid and the Power Smart solar electricity system. Hence, the electricity will be available at the flick of a switch; even at night, or if it is cloudy. The household can install a solar electricity system of any size and the bill will be generated only if the consumption exceeds generation.

- As a 100% efficient system, this electricity will maintain free battery, on top of unlimited 'on-demand' energy, and hence grid-connected solar electricity appears attractive. On top of the benefits of electricity grid, it has an extra advantage of a portion of electricity bill never increasing in price.

(B) Offgrid

- These systems allow to store solar power in batteries for use when the power grid goes down or if are not on the grid. Hybrid systems provide power to offset the grid power whenever the sun is shining and will even send excess power to the grid for credit and for later use.
- These systems do not need to be connected to mains power, as there is no ready source of reserve power. They rely on storage batteries or generators to provide electricity on days when the solar panels generate less electricity than is required.
- System requirements – 1. Suitable solar mounting, 2. Offgrid solar inverter, 3. Solar power controller and batteries, 4. AC and DC safety isolation switches, 5. Grounding earth cables and clamps.

SAFFRON REVOLUTION

- Saffron colour represents energy and Saffron Revolution focuses on renewable energy sources like solar energy to fulfil growing energy demand of India. India's solar potential is huge. Of the world's 20 top economies, it has the most sunlight, especially in the vast deserts.
- Also, solar energy is a way to leap progress over conventional fossil fuel power into twenty-first century's clear energy economy. It would also reduce India's hefty carbon footprint, which comes from relying on coal for 60% of its electricity.

3.6.2.1.1.4 Solar Water Pump

The solar water pumping system uses solar energy to run pump water. There are three main components of any solar water system:

1. Solar PV panel
2. Any motor-pump sets, those will be equipped with the photovoltaic array:
   - Surface-mounted centrifugal pump set
   - Submersible pump set
   - Floating pump set
3. Pipes

Working Mechanism of a Solar Water Pump

This pump operates on solar PV (photovoltaic) system-based power generation. The photovoltaic array converts the solar energy into electricity, which is used for running the motor pump set. Any type of pumping system (either surface pump or submersible pump) draws water from the open well, bore well, stream, pond, canal, etc. The system requires a shadow-free area for installation of the Solar panel.

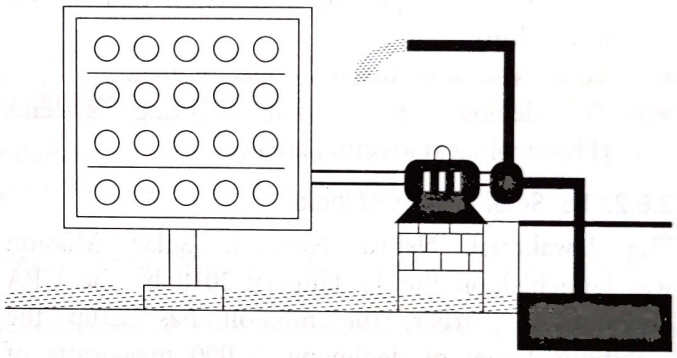


Figure 3.1
Mechanism of Solar Water Pump

Utility

A system with 1800 watt PV array capacity and 2 HP pump can give a water discharge of 1.4 lakh litres per day from a depth of 6 to 7 metres. This quantity of water is considered adequate for irrigating about 5–8 acres of land holding for several crops.

Advantages of a Solar Water Pumping System

1. No fuel cost – as it uses available free sun light.
2. No electricity required.
3. Long operating life.
4. Highly reliable and durable.
5. Easy to operate and maintain.
6. Eco-friendly.

APPROXIMATE COST

Capacity of SPV system	Total Head (Suction & delivery) in m	Solar PV (watt)	Cost (₹)
2 HP (surface pump)	10	1800	2,90,000
4.6 HP (submersible pump)	30	4800	7,15,000

This mission will create an enabling policy to make India a global leader in solar energy. To fulfil this vision, a National Solar Mission is being launched under the brand name 'Solar India'.

Mission Targets

- To create an enabling policy framework.
- To create favourable conditions for solar manufacturing capability (especially solar thermal for indigenous production and market leadership).
- To increase solar thermal collector area.
- To deploy more solar lighting systems (Photovoltaics) for rural areas.

3.6.2.1.1.5 Solar Mission of India

The Jawaharlal Nehru National Solar Mission was launched on the 11 January 2010 by the UPA government. Earlier, the mission has setup the ambitious target of deploying 20,000 megawatts of electricity generations those extended 1,00,000 MW (100 GW) of grid connected solar power by 2022 (by NDA Government) with aim to reducing the cost of solar power generation in the country through

(i) Long-term policy in nation.
(ii) Large-scale deployment goals in India.
(iii) Aggressive research and development; and
(iv) Domestic production of raw materials, components and products to achieve grid tariff parity by 2022.

Note: The 2023 budget identified renewable energy as one of the key seven priorities and the Indian government's commitment to increasing its renewable energy target to 500 GW by 2030 at the COP26 summit has provided great support to the industry and spurred unprecedented growth. However, there is still much work to be done, with a need to install 25–30 GW of solar energy each year for the next eight years to meet its 280 GW solar target. Although solar capacity installations reached a record 14 GW in 2022 and are expected to reach 20 GW in 2023, further support is needed to reach the country's solar potential.

3.6.2.1.1.6 International Solar Alliance (ISA)

It is an international organisation with 114 Members and Signatory countries, which come together to enhance solar energy in the world. These countries are mostly between the Tropic of Cancer and the Tropic of Capricorn due to the high impact of solar radiation to reduce greenhouse gas emission in the atmosphere. This alliance is a treaty-based inter-governmental organisation. This initiative was brought forward by Narendra Modi at the India Africa Summit, and a meeting of member countries ahead of the 2015 United Nations Climate Change Conference in Paris in November 2015. The International Solar Alliance Framework Agreement opened for signatures in Marrakech, Morocco, in November 2016.

Under ISA, there has been an agreement between India and France in January 2016, which jointly laid the foundation stone at the National Institute of Solar Energy (NISE) in **Gwalpahari, Gurgaon.** The Indian government has dedicated five acres of land on the NISE campus for ISA as a future headquarters. France will contribute INR 1.75 billion (US$ 26 million) to build the ISA campus and for meeting expenditures for ISA's first five years. This alliance is also called **International Agency for Solar Policy and Application (IASPA).**

India has already aimed to generate more than 500 gigawatts of renewable energy capacity by 2030 and reducing greenhouse gas emission intensity by 33 to 35% by 2030.

Objectives

- It will promote solar technologies and investment in the solar sector to enhance income generation for the poor.
- It will formulate projects and programmes to promote solar applications.
- It will develop innovative financial mechanisms and reduce capital cost.
- It will unable common knowledge e-Portal build-up.
- It will facilitate capacity building for promotion and utilisation of solar technologies.
- It will promote research and development among member countries.

ISA's Objectives

The ISA's major objectives include global deployment of over 1,000 GW of solar generation capacity and mobilisation of investment of over **US$ 1000 billion** into solar energy by 2030.

ISA brings together countries with rich solar potential to aggregate global demand, thereby reducing prices through bulk purchase, facilitating the deployment of existing solar technologies at scale, and promoting collaborative solar R & D and capacity building.

ISA Framework Agreement entered into the force on December 6th, 2017, headquarters at Gurugram, India.

India announced a goal of obtaining 50% of its electricity from non-fossil fuels by 2030 at the Paris climate change summit, in pursuit of achieving its target of 500 GW by 2030.

Membership

- All members of the United Nations can join the International Solar Alliance (ISA) under the recently amended ISA Framework Agreement.
- **Goal**: It has set a target of 1 TW of solar energy by 2030.

Advantages for India

- Launching of ISA has set up the stage for India's proactive and forward-looking leadership on climate change and the transition to a less carbon-intensive growth trajectory.
- It will also help in bringing down the price of solar technology, which will further help in accelerating the development of the country.
- It will help India to meet its Intended Nationally Determined Contribution target.

Challenges

- **Funding:** Although alliance talks about developing 'innovative financial mechanisms', the way to provide the capital is not fully and clearly addressed.
- **Technology Sharing:** There is need to create a comprehensive framework to share the modern solar technologies at low cost.

ONE SUN, ONE WORLD, ONE GRID (OSOWOG)

This initiative was announced in the **United Nations Framework Convention on Climate Change (UNFCCC) – COP26 [2021] convention** by **India and the United Kingdom** to tap solar energy and have it travel seamlessly across borders.

About the Initiative

- The **grid will be set up over the next few years by the International Solar Alliance (ISA),** another initiative authored by India initially, to transport solar power to different countries.
- The vision behind the OSOWOG is 'The Sun Never Sets' and is a constant at some geographical location, globally, at any given point of time.

Implementation

- A Ministerial Steering Group will work towards accelerating the making of large solar power stations and wind farms in the best locations, linked together by continental-scale grids crossing national borders.
- The Ministerial Steering Group includes France, India, the United Kingdom and the United States, and will also have representatives from Africa, the Gulf countries, Latin America and Southeast Asia.

Significance of World Grid

- With one worldwide grid, we can access clean energy at all places. The need to store energy would also lessen, and the viability of solar projects will increase.

Potential and Benefits of the Initiative

- Following the mantra 'One Sun One Word One Grid' (OSOWOG), India would generate 40% of power from non-fossil fuels by 2030 and has called for connecting solar energy supply across borders.
- The proposed integration would lead to reduced project costs, higher efficiencies and increased asset utilisation for all the participating entities.
- This plan will require only incremental investment because it will not require a parallel grid infrastructure due to working with existing grids.
- It will help all the participating entities in attracting investments in renewable energy sources as well as utilising skills, technology and finances.
- Resulting economic benefits would positively impact poverty alleviation and support in mitigating water, sanitation, food and other socio-economic challenges.
- It will allow national renewable energy management centres in India to grow as regional and global management centres.
- At a global level, almost 2,600 GW of interconnection capacity may be possible up to 2050, delivering estimated power savings of 226 billion euros per year.

3.6.2.1.1.7 Solar Impulse

Solar Impulse is a Swiss long-range experimental solar-powered aircraft project. Solar impulse is also the name of the project's two operational aircrafts. The motives of the project were to make the first circumnavigation of the Earth by a piloted fixed-wing aircraft deploying solar power only, thereby focussing on clean technologies.

The aircrafts are single-seat monoplanes, which are capable of taking off under their own power using photovoltaic cells. The prototype, often known as Solar Impulse 1, was designed to remain airborne for up to 36 hours. In December 2009, its first test flight was conducted and it flew an entire diurnal solar cycle, in July 2010.

A second aircraft, named Solar Impulse 2, was completed in 2014. It carries more solar cells and more powerful motors, besides other improvements. It departed from Abu Dhabi in United Arab Emirates, on 9 March 2015.

3.6.2.1.1.8 Solar Powerhouse

The Cabinet Committee on Economic Affairs approved phase 2 of **the grid-connected rooftop solar programme,** with a focus on the residential sector. **India has set an ambitious target of achieving 40 GW of rooftop solar capacity by 2022. According to a recent report, it had** a shortfall of 25 GW from this target.

Why Uptake Among Residential Consumers has been Slow?

They don't have enough information about it. There is no single source to access information, evaluate benefits and disadvantages and examine if any of the government support (such as a financial subsidy) is available.

Need of the Hour

1. **Devise simple, well-designed and creative ways to disseminate information.** Information must be made easily available to the consumers on the amount of shadow-free roof area needed for generating a unit of electricity and pricing; operating the system, after-sales maintenance and support; and reliable rooftop solar vendors.
2. **The local electricity linesmen, electricity inspectors, and other nodal officials in the electricity department also have key roles to play.** Building their capacities to disseminate such information and handle consumer queries and concerns, and providing basic training in billing and metering for solar power can go a long way in improving consumers' experience.
3. **Objective information must be put out through various avenues,** so that it is accessible to all segments of the population and in local languages. Such awareness drives will reach larger audiences.
4. Information kiosks can be set up in public institutions like banks to offer information on the technology, as well as on practical issues such as guidance on selecting vendors.
5. **A robust feedback mechanism** can be put in place for consumers to share their experiences with others.
6. **Resident welfare associations (RWAs) can tie up with vendors to organise demonstration programmes,** so that consumers can observe, operate and understand how the system works.
7. Awareness building sessions need to **be socially inclusive and should take place during periods when consumers are likely to be at home.**

3.6.2.1.1.9 Floating Solar Plant

India's largest floating solar power plant is in Ramagundam (Telangana) and this place is known for its blistering summer heat. Locally, it is sometimes referred to as 'Agnigundam' (firewell) in Telugu language. Now, the **NTPC (National Thermal Power Corporation)** has grown into **2640 MW capacity** plant, one of its largest sites in the country.

Floating Solar Plants – Significance

- Floating solar plants are considered an **alternate option to tackle land availability issues.** The concept **involves setting up solar panels on floats placed on dams, lakes and similar water bodies.**

Challenges

- In India, floating solar plant is likely to face challenges scaling up to the level of ground-mounted plants.
- Despite being land neutral, the cost of the floating systems including anchoring, installation, maintenance and transmission renders the overall cost of the floating solar systems much higher than the land-based systems at this initial stage of development.

- Besides the two major issues of corrosion and instability, other issues like the long-term impact of moist environment on modules, cables, safe transmission of power through the floats to the nearest feeder point, the environmental impact on the water body and the marine life, etc., needs to be addressed and make the system cost-effective.

Advantages of Floating Solar Power Projects

Floating solar power projects deploy the photovoltaic panels on the surface of water bodies and hence have no issues of land acquisition, leaving the land for other essential uses like agriculture, etc. This improves the performance of solar photovoltaic panels by 5–10%, thus leading to significant cost savings over the time. It will also reduce water evaporation and do improvement of water quality like reduction in algal bloom, etc.

Thus, as a viable alternative to solar installations on land, India has also been making progress in floating solar power. Following are the top upcoming floating solar power projects in India – in planning stage, initial process, or partly under operation.

What Fails Floating Solar?

- Non-availability of floats in India makes it an expensive option.
- Project costs higher by 30–50% than ground mounted solar.
- Dependent on European or Chinese suppliers.

3.6.2.1.1.10 Kisan Urja Suraksha Evam Utthaan Mahabhiyan (KUSUM)

Ministry of New and Renewable Energy (MNRE) has launched the Pradhan Mantri Kisan Urja Suraksha evem Utthan Mahabhiyan (PM KUSUM) Scheme for farmers for installation of solar pumps and grid connected solar and other renewable power plants in the country.

The scheme added solar and other renewable capacity of 30800 MW till 2022 with total central financial support of ₹34,422 crore including service charges to the implementing agencies.

The scheme consists of three components:

1. **Component A:** 10,000 MW of Decentralised Ground Mounted Grid Connected Renewable Power Plants of individual plant size up to 2 MW.
2. **Component B:** Installation of 17.50 lakh standalone Solar Powered Agriculture Pumps of individual pump capacity up to 7.5 HP.
3. **Component C:** Solarisation of 10 lakh Grid-connected Agriculture Pumps of individual pump capacity up to 7.5 HP.

Scheme Implementation

State Nodal Agencies (SNAs) of MNRE will coordinate with States/UTs, DISCOMs and farmers for implementation of the scheme.

Scheme Benefits

The scheme will open a stable and continuous source of income to the rural land owners for a period of 25 years by utilisation of their dry/uncultivable land. Further, if cultivated fields are chosen for setting up solar power project, the farmers will be able to continue to grow crops as the solar panels are to be set up above a minimum height.

The proposed scheme would ensure that sufficient local solar/other renewable energy-based power is available for feeding rural load centres and agriculture pump-set loads, which require power mostly during the day time. There will be reduced transmission losses for STUs and DISCOMs as these power plants will be located closer to the agriculture loads or to electrical substations in a decentralised manner

The solar pumps will not only save the expenditure incurred on diesel for running diesel pump and provide the farmers a reliable source of irrigation through solar pump but also will be preventing harmful pollution caused by running diesel pump.

In light of the long waiting list for electric grid connection, this scheme will benefit 17.5 lakh farmers over a period of four years, without adding to the grid load.

Expected Renewable Energy Target 2030: India has embarked on an ambitious target of having 500 GW of renewable energy by 2030 and also provide **17 lakh solar pumps** to farmers under **Pradhan Mantri-Kusum Yojana** in coming days to capitalise on this clean resource.

3.6.2.1.1.11 Solar Charkha Mission

Specification

- Launched in 2018.
- It is a Ministry of Micro Small & Medium Enterprises (MSME) initiative launched during June 2018.

- The Khadi and Village Industries Commission (KVIC) would implement the programme.
- It seeks to generate employment in rural areas and contribute to the green economy.
- The mission will entail a subsidy of ₹550 crore in the initial two years for 50 clusters and every cluster will employ 400 to 2000 artisans.
- The scheme also aims at linking five crore women across the country to the initiative.
- The mission is expected to create one lakh jobs during the first two years.

Objectives

- To ensure inclusive growth by generation of employment, especially for women and youth, and sustainable development through solar charkha clusters in rural areas.
- To boost rural economy and help in arresting migration from rural to urban areas.
- To leverage low-cost, innovative technologies and processes for sustenance.

SOLAR ENERGY: FACTS CORNER

(I) World's Top 5 Largest Solar Park: on the basis of Power Generation (till Jan 2023)

1. **Golmud Solar Park – China:** The Golmud Solar Park in China is the world's largest solar farm with an installed solar capacity of **2.8 GW**. It's a hugely impressive site with nearly seven million solar panels all working to deliver clean energy.
2. **Bhadla Solar Park – India:** Bhadla, the second largest solar farm in the world, has an astonishing **2.7 GW** capacity and covers an area of **160 km^2** – that's equivalent to **10%** of the entire surface area of London. **(Till 2022, Bhadla Solar Park was the world's largest solar farm on the basis of power generation capacity).**
3. **Pavagada Solar Park – India:** In the third position stood the Pavagada Solar Park that covers an area of **53 km^2**. Pavagada provides **2.05 GW** to Indian citizens and is another exciting slice of the country's developing renewable energy plans. Costing **$2.1 billion**, the solar farm makes up a good chunk of the **$29 billion** India has spent on developing renewable energy since 2018.
4. **Mohammed bin Rashid Al Maktoum Solar Park (MBR) – UAE:** For a nation best known for their vast oil reserves, the United Arab Emirates stood fifth with Mohammed bin Rashid Al Maktoum Solar Park (MBR), covering an area of **76 km^2**. Despite being bigger than the second and third largest solar farms, MBR doesn't *quite* reach the same power output yet. MBR plans to expand its current capacity of **1.63 GW** to around **5 GW** by 2030.
5. **Benban Solar Park – Egypt:** Benban Solar Park in Egypt is Africa's largest solar farm and the fifth largest in the world. It covers the area having a colossal solar potential of **6.3 kWh per m^2 per day**. Costing **$4 billion** and generating **1.61 GW** of clean electricity, Benban provides power to hundreds of thousands of Egyptian homes.

(II) List of Major Solar Parks of India (As in June 2023)

- **Bhadla Solar Park:** Bhadla, Phalodi tehsil, Jodhpur district, Rajasthan, India.
- **Pavagada Solar Park:** Pavagada taluk, Tumkur district, Karnataka.
- **Kurnool Ultra Mega Solar Park:** Panyam mandal of Kurnool district, Andhra.
- **NP Kunta Ultra Mega Solar Park:** also known as Ananthapuram Ultra Mega Solar Park, Ananthapur district of the Indian state of Andhra Pradesh.
- **Rewa Ultra Mega Solar:** Asia's Largest Single site solar plant.
- **Charanka Solar Park** It is currently in the process of development, near Charanka village in Patan district, northern Gujarat.
- **Kamuthi Solar Power Project:** Madurai, in the state of Tamil Nadu, India.
- **Kadapa Ultra Mega Solar Park:** Mylavaram mandal of Kadapa district, Andhra Pradesh.

(III) The Top 5: Upcoming Floating Solar Power Projects in India (As in 2022)

1. Omkareshwar Reservoir: Total capacity - 600 MW, State – Madhya Pradesh
2. Ramagundam Reservoir: Total capacity - 100 MW, State – Telangana
3. Kayamkulam Project: Total capacity - 92 MW, State – Kerala
4. Getalsud Dam Project: Total capacity - 100 MW, State – Jharkhand
5. Rihand Dam: Total capacity - 50 MW, State – Uttar Pradesh

Significance

- These solar charkhas are to be operated using solar power which is a renewable energy source. Being an environment friendly programme, not only will it help in development of Green Economy but will also generate sustainable employment for the artisans.

3.6.2.1.1.12 World's Largest Solar Tree

CSIR-CMERI develops world's largest 'Solar Tree'

To promote the usage of solar energy, a leading CSIR institute **'Central Mechanical Engineering Research Institute' has developed 'world's largest solar tree' which was inaugurated in Ludhiana** in the recent past. It is officially certified by **Guinness World Records (GWR) as the 'Largest Solar Tree' in the world**. The entire solar PV panel surface area is 309.83 square metres and is used in mini grid application and rural electrification. It is designed to resemble a tree, where the 'leaves' of the tree are fitted with solar panels.

Significance and Potential of Solar Trees

- These Solar Trees can be **aligned with Agriculture** for **substituting price-volatile fossil fuels.**
- Each Solar Tree has the potential **to save 10–12 tons of CO_2 emissions** being released into the atmosphere as greenhouse gases when compared with fossil fuel-fired energy generation.
- Besides, the surplus generated power can be fed into an Energy Grid.
- This Agricultural Model can provide **a consistent economic return and help the farmers counter the effects of the uncertain variations** in agriculture related activities, thus, making farming an economic and energy sustainable practice.
- The solar tree also has **the capability to incorporate IoT-based features,** i.e., round-the-clock CCTV surveillance in agricultural fields, real-time humidity, wind speed, rainfall prediction and soil analytics sensors.
- The CSIR-CMERI-developed solar-powered e-Suvidha Kiosks may also be connected to the Solar Trees for real-time access to the vast majority of agricultural database as well as to the eNAM, i.e., National Agricultural Market which is the place for instant and real-time access to a unified online market.

3.6.2.1.2 Wind Energy

Wind turbine nowadays is capable to utilise wind for electricity generation. It is a specific property of blade which is developed with specific aerodynamic shape and other performance-enhancing equipment. To take advantage of faster and less turbulent winds, they need to be mounted at 100 feet (30 metres) or more above ground.

- When blowing wind turns the wing, it will utilise to generate electricity with the help of generator attached.
- However, this rotation cannot be directly coupled to a generator, because the wind turbine blades connected with shaft, typically turn at very low rate of rpm due to the issues of its noise and mechanical strength.
- At this low speed of rotation, generator cannot produce any meaningful electricity. So before connecting to the generator the speed of shaft is increased in a gearbox. The gearbox uses a planetary gear set arrangement to increase the high speed ratio (up to 1:90).
- Minimum wind speed required for power generation is 8 km/hour (or 2 mt/sec) and in maximum speed which can be used for power generation is reported to be 36–54 km/hour. 10–12 km/hour is the average speed of wind in India.
- **Wind vane** is utilised to check wind direction.
- Wind direction can change at any time. A velocity sensor is fitted on the top of the nacelle which measures the wind speed and direction.
- The deviation in the winds direction is sent to an electronic controller which in turn sends an appropriate signal to the yawing mechanism to correct the error. Thus, the wind turbine will always be aligned with the wind direction.
- According to the wind-speed the relative velocity angle of the wind also changes.
- A blade tilting mechanism tilts the blade and guarantees a proper alignment of the blade with the relative velocity. Thus the blades are always at the optimum angle of the attack with the relative wind flow.
- Maximum limit that a wind turbine can achieve is called as Betz's limit. No wind turbine in this world can ever cross the efficiency limit of 59.3%.

Characteristics

- A clean and safe energy source, which is the most environment friendly.
- As compared to other plants, it has the lowest gestation period.
- Less time for set-up.
- Low operating costs.
- Low maintenance cost.

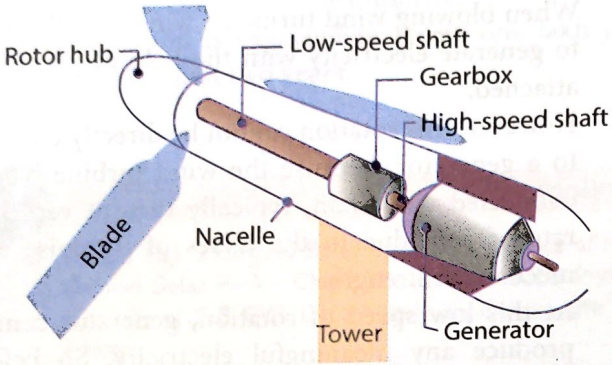


Fig. 3.2
Nacelle

(Refer **Infographic – Wind Energy Generation**)

In 1986, the development of wind power in India began with the first wind farms being set up in coastal areas of Maharashtra (Ratnagiri), Gujarat (Okha) and Tamil Nadu (Tuticorin) with 55 kilowatts Vestas wind turbines.

MNRE supported these demonstration projects.

China has the maximum wind power generation capacity in the world but America is the country, which has the maximum wind energy generation (production).

In India, **Tamil Nadu** is a leading state for wind energy generation. The maximum wind power capacity among Indian states is that of Tamil Nadu, with around 29% of India's total wind power capacity. Thereafter, realising the importance and need for renewable energy, a separate agency was set up by Tamil Nadu government, as early as in 1985, as a registered society. It was named the **Tamil Nadu Energy Development Agency (TEDA).**

Recent Updates: With an installed capacity of 42633 MW (March 2023) of Wind Energy, Renewable Energy Sources (excluding large Hydro) currently accounts for 30.08% (125160 MW) of India's overall installed power capacity of 416059 MW (31 March 2023).

OFFSHORE WIND POLICY, 2

Establishment of offshore wind power projects and research and development activities, in waters, in or adjacent to the country, up to the seaward distance of 200 Nautical Miles (EEZ of the country) from the base line, etc., are all included under offshore wind energy development.

Initially, the 7600-kilometre long Indian coastline indicated prospects of development of offshore wind power and hence the development would smoothen the country's way to attain energy security and achievement of the NAPCC (National Action Plan on Climate Change) targets. As per the offshore wind potential availability, the scheme would be applicable throughout the country.

In the wind sector, about 2.28 GW of new capacity was added in FY2023, which is 105% higher than the 1.1 GW capacity added in FY2022. **Rajasthan is the leading state** with installed capacity of 867 MW in wind in FY2023, followed by **Gujarat (770 MW)** and **Madhya Pradesh (324 MW).**

3.6.2.1.3 Geothermal Energy

The heat from the Earth generates another renewable (that is clean and sustainable) form of energy called geothermal energy.

At a depth of more than 80 km, heat is available normally. In certain location at a depth of 300–3000 mt have also presented the presence of geothermal energy, i.e., called as **geothermal field.** World's first geothermal power plant was set up in **Larderello (Italy)** in 1911.

There are three types of Geothermal Power Plant setups worldwide:

1. Dry Steam Power Plant
2. Flash Steam Power Plant – Geothermally heated water (temperature over 350 Fahrenheit)
3. Binary Cycle Power Plant – Geothermally heated water (temperature up to 100 Fahrenheit)

Ranging from the shallow ground to hot water and hot rocks found a few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma, various potential resources of geothermal energy are found.

1. Dry Steam Power Plant

Dry steam ***power plants are the most common types of*** geothermal ***power plants, accounting for about half of***

the installed geothermal *plants. They* work *by piping hot* steam *from underground reservoirs directly into turbines from* geothermal *reservoirs, which power the generators to provide electricity.*

2. Flash Steam Power Plant

Flash steam power plants take high-pressure hot water from deep inside the earth and convert it to steam to drive generator turbines. When the steam cools, it

condenses to water and is injected back into the ground to be used again. Most geothermal power plants are flash steam plants.

3. Binary Cycle Power Plant

Binary Cycle Power Plant: Binary cycle geothermal power generation plants differ from Dry Steam and Flash Steam systems in that the water or steam from the geothermal reservoir never comes in contact with the turbine/generator units.

A binary vapour cycle is defined in thermodynamics as a power cycle that is a combination of two cycles, one in a high temperature region and the other in a lower temperature region.

(Refer **Infographic – Geothermal Power Energy Generation**)

General characteristics of geothermal energy: **1.** High accessibility and global availability, **2.** Environment friendly in nature, **3.** Low emission of sulphur, CO_2 and other greenhouse gases, **4.** Indigenous, **5.** Does not depend on weather and seasonal changes.

According to **India Energy Portal, India has a geothermal potential of 10,000 megawatts (10 GW).** The Tattapani (Himachal Pradesh) geothermal field is the most promising geothermal resource in central India. The promising geothermal sites for direct heat use applications are **Rajgir** in Bihar, **Manikaran** in Himachal Pradesh, **Surajkund** in Jharkhand, **Tapoban** in Uttarakhand and **Sohana** region in Haryana. More than 300 sites of geothermal energy sources are identified in India. There are seven geothermal provinces in India – **Himalayan (Puga, Chhumathang), Sahara Valley, Cambay Basin, Son–Narmada–Tapi (SONATA) lineament belt, West Coast, Godavari basin** and **Mahanadi basin.**

3.6.2.1.4 Ocean Energy

Around 70% of Earth's surface is covered by ocean and hence they are the world's largest solar collectors. **Ocean has also become a source of energy generation in modern prospective.** ***Thermal energy from the Sun's heat and mechanical energy from the tides and waves are the reason of energy produced by ocean.***

There are three forms of electricity generations from sea:

1. **Tidal Energy**
2. **Wave Energy**
3. **Ocean Thermal Energy**

1. **Tidal Energy:** The gravitational pull of the moon is primarily responsible for tides in ocean. In this case a water reservoir is connected with ocean water. Due to up (high tide) and down (low tide) of water level, fluctuation start in water reservoir either water starts to enter inside the reservoir due to upliftment of water in ocean or it starts to move outside from the reservoir during downward movement (low tide) of ocean water. During both the processes, connected turbine or rotor will move and generate mechanical energy; those will further convert into electricity by the use of dynamo.
2. **Wave Energy:** In this type of ocean energy generation, **turbine is installed inside the ocean** and they will move during the effect of ocean current. This mechanical energy of turbine will be converted into electricity with the help of dynamo.
3. **Ocean Thermal Energy:** The surface water of ocean is heated more by Sun's heat, than the deep ocean water. The temperature difference thus created results in thermal energy. It is estimated that the whole world can be powered even with a small portion of the heat trapped in the ocean. In this system, hot water of upper layer of ocean will go in a chamber containing volatile liquid (Liquid Ammonia), which starts to vaporise (Gas) and finally leads to steam formation. This steam pressure will be used to move a turbine and mechanical energy generated can be utilised for electricity generation with the help of generator. Vaporised gas/steam will further cool down when it will come in contact with lower part of ocean which has low temperature. This type of system will work in those areas of ocean where temperature difference between hot water (upper surface of water) and cold water (down inside in ocean) should be at least 20°C.

Potential of Tidal Energy in India

The **Gulf of Cambay** and the **Gulf of Kachchh** on the west coast, maximum tidal ranges are of 11 metres and 8 metres and an average tidal ranges are of 6.77 metres and 5.23 metres, respectively. These are the most attractive locations in India.

Even the **Ganges Delta in the Sunderbans** in West Bengal offers good locations for small-scale tidal power development. Sunderbans have the maximum capacity of approximately 5 metres, with an average tidal range of 2.97 metres.

(Refer Infographic – Tidal Energy)
(Refer Infographic – Ocean Thermal Energy)

3.6.2.1.5 Hydropower

Hydroelectric power **or** hydropower represents electricity that is generated after capturing flowing water. Usually, the hydroelectric power plant uses a dam on a river for water storage in a reservoir. Water released from the reservoir flows through a turbine, resulting in spinning of turbine, producing mechanical energy to activate a generator, which finally converts it to electrical energy.

A pumped storage plant which can even store power is known as another type of hydroelectric power plant. Enough amount of electricity for a home, farm or a ranch can be produced by small or micro-hydroelectric power system.

India is the 5th globally for installed hydroelectric power capacity. One of the largest hydroelectric power potentials in the world is that of 1,48,700 megawatts at 60% load factor. The hydroelectric power plants at Darjeeling (in 1898) and Shivanasamudra (in 1902) were among the first in Asia. In terms of global hydro power development, India enjoys a dominant status, being blessed with immense amount of hydroelectric potential. It ranks fifth in terms of exploitable hydropotential on a global scale.

Classification of Hydro Projects based on Installed Capacity

- **Micro:** up to 100 kW.
- **Mini:** 101kW to 2 MW.
- **Small:** 2 MW to 25 MW.
- **Mega:** Hydro projects with installed capacity ≥ 500 MW.

3.6.2.1.6 Biomass Energy

It includes solid biomass (organic, non-fossil material of biological origins), biogas (principally methane and carbon dioxide that is produced by anaerobic digestion of biomass), liquid biofuels (bio-based liquid fuel from biomass transformation, mainly used in transportation applications) and municipal waste (wastes produced by the residential, commercial and public service sectors and incinerated in specific installations to produce heat and/or power).

3.7 SOME RECENT AND ADVANCED ENERGY GENERATION SOURCES

3.7.1 Fuel Cell/Hydrogen Fuel Cell

A fuel cell converts the chemical energy from a fuel into electricity through a chemical reaction of positively charged hydrogen ions with an oxidising agent like oxygen.

Difference between Battery and Fuel Cell

The biggest difference between the battery and the fuel cell is that a battery stores energy, while a fuel cell generates energy by converting the available fuel. A fuel cell can have a battery as a system component to store the electricity it is generating. An energy storage device is a battery, which stores its fuel internally. On the other hand, the fuel cell is an energy conversion device, wherein the fuel is supplied externally. A battery runs down as the electrodes dissolve, but a fuel cell operates for as long as oxygen and hydrogen flow and hence in terms of the durability, fuel cell is advantageous over battery. Both generate Direct Current (DC).

Working and Technology of Fuel Cell

A fuel cell is an electrochemical device, in which the hydrogen fuel combines with oxygen to produce electricity, heat and water. The fuel cell is similar to a battery in that an electrochemical reaction occurs as long as fuel is available. Hydrogen is stored in a pressurised container and oxygen is taken from the air. Because of the absence of combustion, there are no harmful emissions, and the only by-product is pure water. It can be used at all levels of electrical appliances from small (e.g., phone battery) to large (e.g., Rocket).

Applications of Fuel Cells

1. Fuel cells provide an all-weather solution that can keep providing power even though weather conditions prevent site visits.
2. Fuel cells can communicate data using our REMO (Remote Monitoring System).
3. Powering temporary buildings.
4. Transport (rail, road and air).

5. Materials handling.
6. Blue light and defence applications.
7. Cellular base stations.
8. Power generation.

Electrolytes: These are those substances which give ions when dissolved in water. They can be any acid, base or salts because all of them generate ions when dissolved in water. **Platinum is mostly used as electrolytes.** These solutions conduct electricity due to the mobility of the positive and negative ions, which are called cations and anions, respectively. Strong electrolytes completely ionise when dissolved, and no neutral molecules are formed in solution. For example, NaCl, HNO_3, $HClO_3$, $CaCl_2$, etc., are strong electrolytes. An ionisation can be represented by

$$NaCl(s) = Na^+(aq) + Cl^-(aq)$$

Advantages of a Fuel Cell

- The cell will generate a voltage as long as it gets the fuel supply.
- The amount of oxygen and hydrogen (and not the size of the fuel cell) determines the total amount of energy generated.
- Recharging is not required.

Future of Fuel Cells

1. For automotive engines, power stations and the power packs for portable electronics, fuel cells have the potential to become the dominant technology in future.
2. They will compete with different energy conversion devices.
3. The turbine and the gasoline engine (types of combustion engine) burn fuels and use the pressure created by the expansion of the gases to perform mechanical work. When required, the batteries convert chemical energy back into electrical energy. Both the tasks can be accomplished by the fuel cells more efficiently.
4. One of the most promising technologies is the proton exchange membrane fuel cell (PEMFC). This type of fuel cell will enable powering cars, buses and maybe even houses.

How is Hydrogen Produced?

Hydrogen does not exist on Earth as a gas, and hence is required to be separated from other compounds. Hydrogen can be usually produced by electrolysis (water splitting) and steam reforming. The least expensive method among these three is steam reforming. In industries, hydrogen can be separated from carbon atoms in methane. The process of steam reforming causes greenhouse gas emissions, which contributes to global warming because methane is a fossil fuel.

The other process is electrolysis, which involves passing an electric current through water to separate water into its constituent elements – hydrogen and oxygen. At the negatively charged cathode, hydrogen is collected, while oxygen is collected at the positive anode. We get extremely pure hydrogen through electrolysis, leading to no emissions since electricity from renewable energy sources can be used. However, it is a very expensive process.

Other processes include photo-electrolysis and biomass gasification. Some algae and bacteria have also been identified to produce hydrogen under certain conditions, with the help of sunlight as their source of energy.

The Future of Hydrogen

In the future, it is expected that hydrogen as a fuel will play an important role as an energy carrier, because its production can be made by using renewable energy sources and it virtually does not cause pollution. Applicable for **'zero-emissions'** vehicles, to heat homes and offices, to produce electricity, and to fuel aircraft, hydrogen proves to be a potential fuel for future, hence reducing dependence on oil. However, to be used as an alternative to gasoline, it requires many new facilities and systems.

Wind electrolysis system is another method of hydrogen production. The way it works is: The hydrogen is compressed up to pipeline pressure to be fed into a transmission pipeline, which further transports the hydrogen to a compressed gas terminal where the hydrogen is loaded into compressed gas tube trailers. The tube trailers are delivered by a truck to a forecourt station. Here, the hydrogen is further compressed, stored and dispensed to fuel cell vehicles.

3.7.2 Microbial Fuel Cells (MFCs)

A microbial fuel cell is very similar to hydrogen fuel cell but in place of hydrogen fuel, organic waste (sewage water, etc.) is used. In hydrogen fuel cell, platinum is used as an electrolyte/catalyst but in microbial

fuel cells, organic waste decomposes/breaks in the presence of bacteria as a catalyst, that generates H^+/ proton. **Bacteria have the ability to convert a variety of organic compounds into CO_2, water and energy.** The energy produced by the microorganism is utilised to grow and maintain their metabolism. By using MFC, we can harvest this energy in the form of electricity.

Components of MFC: The MFC comprises of an anode, a cathode, a proton or a cation exchange membrane and an electrical circuit.

Functional Activity of Microbial Fuel Cell: The bacteria are put in an anode chamber where they convert organic compounds/substrates into CO_2, proton (H^+), electron, etc. Through the help of proton exchange membrane, protons will transfer from anaerobic chamber to aerobic chamber. In aerobic chamber, protons (H^+) bind with oxygen and form water as a by-product. In this process, the excess electrons left in anaerobic chamber start to move from anode to cathode through an electric circuit. This movement of electrons due to potential difference is responsible for the generation of electrical power (watt).

In MFC, the bacteria is put in an anode compartment where it converts organic substrate such as glucose, acetate into CO_2, protons and electrons and also waste water. The electrons from the anode chamber flow to the cathode chamber through an electrical circuit with a load or a resistor. The flow of electrons (Ampere) between the anode and the cathode due to potential difference between anode and cathode (Volt) results in the generation of electrical power (Watt). The flow of protons is through the proton or cation exchange membrane to the cathode. The electron acceptor is chemically reduced at the cathode. Ideally, reduction of oxygen to water takes place. A platinum catalyst is required to obtain sufficient oxygen reduction reaction (ORR) rate in Hydrogen fuel cell but in **MFCs, this role is performed by bacteria as a catalyst. MFCs can also be applied in waste water treatment due to presence of organic substances.**

(Refer **Infographic – Hydrogen Fuel Cell and Microbial Fuel Cell**)

3.7.3 Lithium Ion (Li-ion) Battery

It is very popular and highly useful battery in modern prospective in many electronic equipment like mobile phones, laptops, e-readers and many other electronic gadgets as well as electric vehicles and power tools, etc.

Growth and Development of Li-Ion Batteries

- Lithium battery technology has distinct advantages over other older rechargeable battery technologies such as Nickel cadmium and Nickel Metal Hydride.
- The idea for lithium ion battery technology was first proposed in the 1970s by M Whittingham who used titanium sulphide and lithium metal as the electrodes for his cell.
- Lithium ion battery has three main components: Cathode, Anode and Electrolytes.
- Due to its main charge carrier through lithium ions it is called as lithium ion battery. Lithium ions flow due to cathode and anode material into which and from which the lithium ions can flow. There are two processes involved during lithium ion movement.
- Separators are also used to safeguard this battery so no chances of short-circuit inside battery. In lithium ion battery anode is made up of graphite; cathode is made up of lithium metal (cobalt/ nickel) oxide.
- In electrolytes, water molecule should be negligible. When we provide a load (An electrical load is an electrical component or portion of a circuit that consumes electric power).
- During discharge, the (positive) lithium ions move from the negative electrode (anode) (usually graphite – C6) to the positive electrode (cathode) (forming a lithium compound) through the electrolyte while the electrons flow through the external circuit in the same direction.
- When the cell is charging, the reverse occurs with the lithium ions and electrons move back into the negative electrode in a net higher energy state.
- This entire process is called as intercalation and de-intercalation. Intercalation is a process when battery is going to discharge but in de-intercalation process battery will charge again when lithium ions are extracted from the electrode.

TABLE 3.4 Types of Lithium ion batteries and its uses

Applications	Types of Lithium Ion Batteries
Cellphones, laptops, cameras	• Lithium Cobalt
Power tools, medical, hobbyist	• Lithium Manganese Oxide • Lithium Iron Phosphate • Lithium Nickel Manganese Cobalt Oxide
Electric vehicles and grid storage	• Lithium Nickel Cobalt Aluminium Oxide • Lithium Titanate

Features of Li-Ion Battery Which Made it Better Among other Batteries

- **Don't totally discharge:** Lithium-ion batteries should be charged before the battery is completely discharged. This is probably the single most important factor in general usage. Leaving them to become totally discharged considerably shortens their life. For example, it is often recommended that smart phones (which use Li-ion batteries) should be charged when they reach 10–20% of their charge. Also, Li-ion batteries should never be depleted to below their minimum voltage, 2.4 V to 3.0 V per cell.
- **Non-use care:** If a Li-ion battery is not to be used for an extended period of time, it should ideally be brought to a charge level of between about 40% and 60% of full charge. Ideally it should be periodically charged to overcome the effects of self-discharge (around 2% per month).
- **Keep cool:** Li-ion batteries should be kept cool. By keeping them cool, possibly in a refrigerator, the ageing process becomes slower. As a result, Li-ion batteries should not be kept in cars on sunny days as the temperatures rise significantly.
- **Don't freeze:** Li-ion batteries should not be exposed to very low temperatures – most lithium-

LITHIUM-ION BATTERY

When lithium-ion batteries are in use, the cathode side experiences an increase in positive potential, causing it to attract electrons from the anode side due to the higher electron concentration present there.

Separator

ion battery electrolytes freeze at approximately –40°C. This may exclude them from some applications where equipment needs powering in extremes of temperature.

- **Buy new batteries only when needed:** Li-ion batteries should be bought only when needed, because the ageing process begins as soon as the battery is manufactured.

Note: According to **International Energy Agency Report (2022)**: Contribution of different source of batteries, worldwide

1. 60% Lithium
2. 30% cobalt
3. 10% Nickel

More than 70 per cent of the world's cobalt is produced in the Democratic Republic of the Congo (DRC).

3.7.4 FAME-India Scheme

FAME India is a part of the **National Electric Mobility Mission Plan. Main thrust of FAME is to encourage electric vehicles by providing subsidies.**

- Vehicles in most segments – two wheelers, three wheelers, electric and hybrid cars and electric buses obtained the subsidy benefit of the scheme.
- FAME focuses on four areas, i.e., Technology development, Demand Creation, Pilot Projects and Charging Infrastructure.
- The Union Cabinet has approved the proposal for implementation of scheme titled **'Faster Adoption and Manufacturing of Electric Vehicles in India Phase II (FAME India Phase II)'** for promotion of Electric Mobility in the country.
- The scheme with total outlay of ₹10000 crores over the period of three years will be implemented with effect from 1 April 2019.
- This scheme is the **extended version of the present scheme titled 'FAME India 1'** which was launched on 1 April 2015.

FAME 2 Scheme

The Department of Heavy Industry approved the sanction of 5595 electric buses to 64 cities, State Government Entities, State Transport Undertakings (STUs) for intra-city and intercity operation under FAME India scheme phase II in order to give a further push to clean mobility in public transportation.

Salient Features of FAME II Scheme

- Faster Adoption and Manufacturing of Hybrid and Electric Vehicles, or FAME II scheme aims to boost electric mobility and increase the number of electric vehicles in commercial fleets.
- Target: The outlay of ₹10,000 crore was made for three years with effect from 1st April 2019.
- The government offered the incentives for electric buses, three-wheelers and four-wheelers to be used for commercial purposes.
- Plug-in hybrid vehicles and those with a sizeable lithium-ion battery and electric motor were also included in the scheme and fiscal support offered for depending on the size of the battery.

How will FAME-II Scheme Help Improve Charging Infrastructure?

- The centre will invest in setting up charging stations, with the active participation of public sector units and private players.
- It has also been proposed to provide one slow-charging unit for every electric bus and one fast-charging station for 10 electric buses.
- Projects for charging infrastructure will include those needed to extend electrification for running vehicles such as pantograph charging and flash charging.
- FAME II will also encourage interlinking of renewable energy sources with charging infrastructure.

3.7.5 Government Policies of 2021 to Help Boost EV Adoption

In a thrust towards incentivising new age technologies and fulfilling the pledge taken at COP26 to reduce its carbon emissions to net zero by the year 2070, India is aggressively promoting the adoption of Electric Vehicles (EVs).

Aim

India aims to switch 30% of private cars, 70% of commercial vehicles, and 80% of two and three-wheelers to EVs by the year 2030. For this, both the central and state governments are offering various incentives to buyers and manufacturers.

Various Measures Undertaken Include

- **PLI Scheme for Auto Sector:** In September this year, the Union Cabinet approved a ₹26,058 crore production-linked incentive (PLI) scheme to accelerate domestic manufacturing of electric and fuel cell vehicles and drones in India.
- **FAME II Amendment:** Under FAME-II (Faster Adoption and Manufacturing of Electric Vehicles-II) scheme, the government significantly reduced the price gap between petrol-powered two-wheelers and electric ones by increasing the subsidy rate for electric two-wheelers.
- **Scrappage Policy:** On 13 August 2022, the government launched the Vehicle Scrappage Policy virtually at the Gujarat Investor Summit. The policy aims to phase out unfit and polluting vehicles in an environment-friendly manner. Along with the centre, state governments are also leaving no stone unturned to promote faster adoption of EVs in India. To increase penetration and adoption of battery electric vehicles (BEVs), governments of around 20 states in India, including Delhi, Gujarat, Goa, Maharashtra and Rajasthan have already come up with either a draft or final state level EV policies. Recently in February 2023, the Ministry of Road Transport of the Central Government issued a draft notification in which 15-year-old vehicles of the Central and State Governments will have to be scrapped.

Challenges Ahead

- The Indian EV market currently has one of the lowest penetration rates in the world.
- Capital costs are high and the payoff is uncertain.
- The Indian EV industry has been hit hard due to rupee's dramatic depreciation in recent months.
- Local production of inputs for EVs is at just about 35% of the total input production.
- The production will be severely affected in terms of production costs.
- The Faster Adoption and Manufacturing of (Hybrid) and Electric Vehicles (FAME) framework has been extended repeatedly.
- An uncertain policy environment and the lack of supporting infrastructure are major roadblocks.
- India does not have any known reserves of lithium and cobalt which makes it dependent on imports of lithium-ion batteries from Japan and China.

Need of the Hour

- For EVs to contribute effectively, we need to commensurate efforts in developing an entire ecosystem.
- Need to shift the focus from subsidising vehicles to subsidising batteries because batteries make up 50% of EV costs.
- Increasing focus on incentivising electric two-wheelers because two-wheelers account for 76% of the vehicles in the country and consume most of the fuel.
- A wide network of charging stations is imminent for attracting investment.
- Work places in tech parks, public bus depots and multiplexes are the potential places where charging points could be installed. In Bangalore, some malls have charging points in parking lots. There are 1397 EV charging stations in India spread across 216 cities till July 2023. Of these, Maharashtra has the highest number with 1556 charging stations while Pondicherry has the least with 2 charging stations.
- Corporates could invest in charging stations as Corporate Social Responsibility compliances.
- Acquiring lithium fields in Bolivia, Australia and Chile could become as important as buying oil fields as India needs raw material to make batteries for electric vehicles.

3.7.6 Waste to Power/Energy

Any organic waste, which can be degraded, is a resource that can lead to energy generation. By adopting environment-friendly, waste-to-energy conversion technologies, the issues caused due to solid and liquid wastes can be significantly mitigated. This will enable treatment and processing of wastes before their disposal that can reduce the quantity of wastes and generate a substantial quantity of energy from them, substantially leading to environment pollution.

Types of Waste: Wastes can be mainly classified into

- Urban waste
- Industrial waste

- Biomass waste
- Biomedical waste

Energy from Waste Technologies: The organic fraction of waste (biodegradable as well as non-biodegradable) can recover energy through thermal, thermo-chemical, biochemical and electrochemical methods.

1. **Thermal conversion:** Incineration is a major technological option; however, due to its emission features, it is losing attention these days.
2. **Thermo-chemical conversion:** Application is for wastes containing high percentage of organic non-biodegradable matter and low moisture content. Pyrolysis and gasification are main technological options under this category.
3. **Bio-chemical conversion:** Anaerobic digestion (bio-methanation) and fermentation are the major technological options under this category.
4. **Electrochemical conversion:** Electrochemical conversion in terms of energy waste refers typically to microbial fuel cells (MFC).

3.7.7 Polycrack Technology

- The ***country's first Government-Owned Waste-to-Energy Plant*** was commissioned in 2020 at the Mancheswar Carriage Repair Workshop in ***Odisha.***
- The plant, a patented technology called *Polycrack, is first-of-its-kind in the Indian Railways and fourth in the country.*
- It *converts multiple feed stocks into hydrocarbon liquid fuels, gas, carbon and water.*

What is Polycrack?

- It is ***the world's very first patented heterogeneous catalytic process which converts multiple feedstocks into hydrocarbon liquid fuels, gas, carbon as well as water.***
- The waste generated will become the feeder material for the waste to energy plant.
- The energy which will be produced at the plant will be in the form of light diesel oil and this oil will be used to light furnaces.

The plant, having a capacity of 500 kg per batch, can be fed with the following

- All kinds of existing plastic
- Petroleum sludge
- Unsegregated MSW (Municipal Solid Waste) with moisture up to 50%
- E-waste
- Automobile fluff
- Organic waste including bamboo, garden waste
- Jatropha fruit and palm bunch

Some of the Advantages of this Plant are as Follows

- ***The pre-segregation of waste is not required for processing in the plant.*** The waste as collected from the source can be directly fed into the polycrack plant.
- The plant has ***high tolerance to moisture hence drying of the waste after treatment is not required.***
- The waste is processed in the plant and reformed within a period of 24 hours.
- The biological decomposition is not allowed as the waste is treated in the plant as it is received.
- ***All the constituents are converted to valuable energy therefore, making it a zero discharge process through the plant.***
- The gas generated in the process of the plant is reused in order to provide energy to the system, hence making itself reliant and self-sufficient for its energy requirements. This also brings down the operating cost of the plant.
- ***The plant does not cause atmospheric emission during the process*** unlike the other conventional methods except for the combustion of gases which have pollutants less than the prescribed norms across the world.

3.7.8 Biomass Gasification

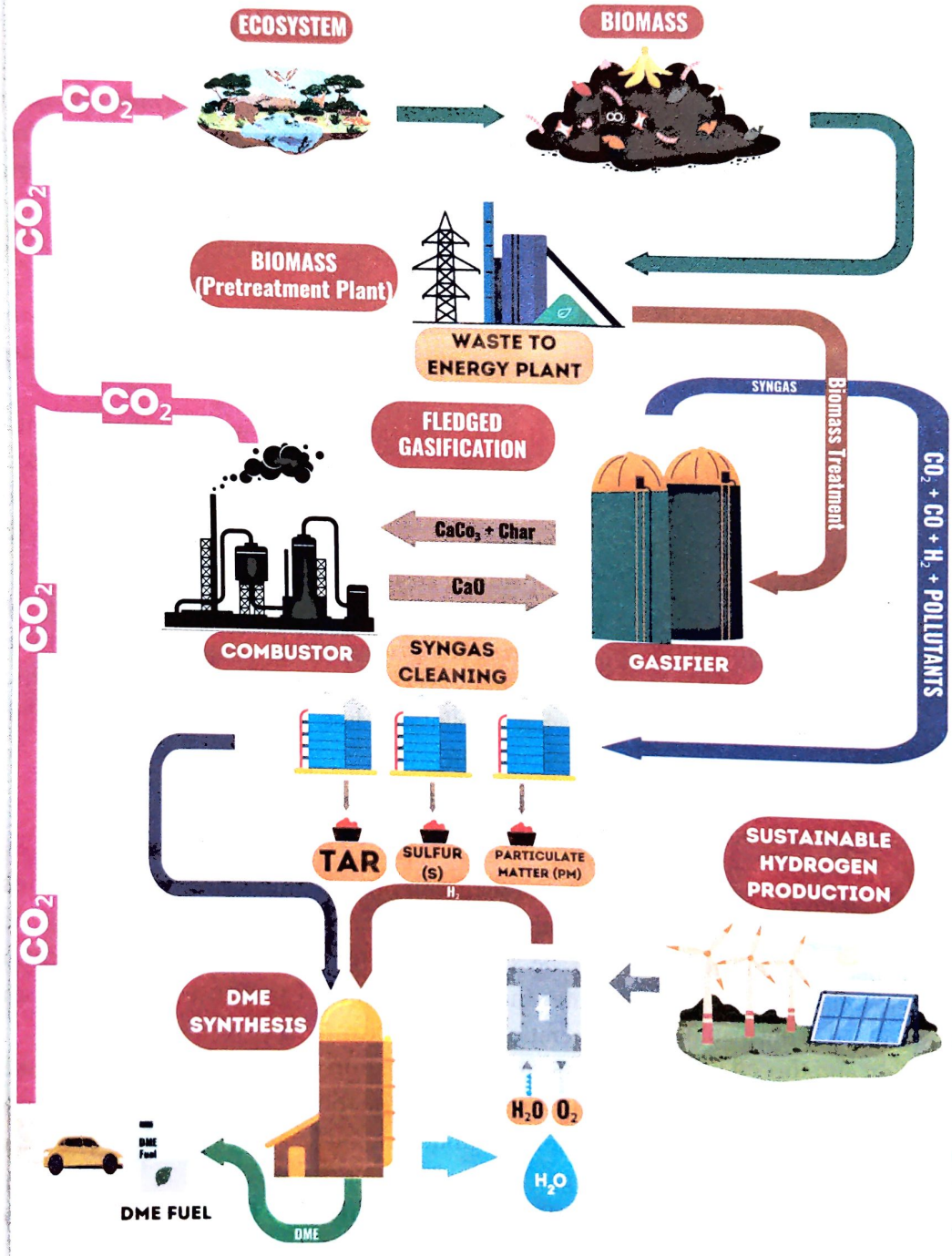
Coconut shell, coir pith, rice husk, firewood, coffee husk and other industrial wastes are those solid wastes which can be converted into producer gas by gasification route. The gas so produced can be used for heating and generation of electricity.

Biomass gasification follows pyrolysis processes, which represents the direct thermal decomposition of biomass under closed chamber (in the absence of oxygen).

(Refer **Infographic – Biomass Gasification Process**)

BIOMASS GASIFICATION

Biomass gasification follows pyrolysis process, which represents the direct thermal decomposition of biomass under closed chamber (in the absence of oxygen). Hence, it prevents direct combustion, to obtain an array of solid (bio-char), liquid (bio-oil) and gas (syngas) products. When biomass burns at temperatures of 400–500 °C, it produces more char, while temperatures above 700 °C favours the yield of liquid and gas fuel components. Gasification is a process in high temperature pyrolysis, which primarily produces syngas/producer gas. It mainly consists of carbon monoxide and hydrogen.



ECOSYSTEM

Plants and certain organisms containing chlorophyll utilize the energy from sunlight to convert carbon dioxide into oxygen and biomass through the process of photosynthesis.

BIOMASS

Biofuel production can make use of the readily available woody and waste biomass resources.

BIOMASS PRETREATMENT

To decrease its size and moisture content, biomass undergoes pretreatment.

Fledged Gasification

GASIFIER

The gasifier uses steam and produces hydrogen, carbon dioxide, carbon monoxide, and char. Adding solid calcium oxide reacts with carbon dioxide, creating calcium carbonate and allowing for fine-tuning the syngas composition to match downstream process requirements.

COMBUSTOR

By burning the residual char from the gasifier with air, the calcium carbonate undergoes decomposition, resulting in the regeneration of calcium oxide and the release of carbon dioxide.

SYNGAS CLEANING

To ensure compliance with the specifications of the Dimethyl Ether (DME) synthesis reactor, the syngas is subjected to a purification process aimed at eliminating pollutants like tar, sulfur, and particulate matter.

SYNTHESIS OF DME

In a unique **FLEDGED** catalytic reactor, the clean syngas undergoes conversion into **DME**. To improve the DME yield, a porous sorbent is utilized within the reactor to remove the steam produced during the process.

PRODUCTION OF SUSTAINABLE H_2

Renewable electricity can be used for water electrolysis to produce additional hydrogen, which can then be utilized to enhance DME production and support power-to-liquid conversion.

FINAL USE OF DME

DME has the potential to serve as a biofuel, replacing conventional fossil fuels and thereby promoting sustainability in the automotive sector.

TERMINOLOGY RELATED TO BIOMASS GASIFICATION

- **Pyogenic Carbonaceous Material (PCM)** are those which are produced by thermochemical conversion and contain some organic carbons, such as char, charcoal, biochar, ash, activated carbon, black carbon, soot, etc.
- **Char:** The incomplete combustion processes occurring in natural and man-made fires generate materials called as 'Char'.
- **Charcoal:** The thermochemical conversion from biomass (mainly but not exclusively wood) for energy generation produces charcoal.
- **Ash:** The operationally defined fraction of biomass or PCM, which typically includes inorganic oxides and carbonates.
- **Gasification:** This is a process of converting organic materials into carbon monoxide (CO), hydrogen (H), carbon dioxide (CO_2) and methane (CH_4) through really high temperatures, without combustion (burning).
- **Coal Gas:** It is a gaseous mixture of mainly hydrogen, methane and carbon monoxide together, made by the destructive distillation (i.e., heating in the absence of air) of bituminous coal and used as a fuel. Steam, when added to it, reacts with the hot coke, increases the yield of gas, which yields Coal tar and coke as by-products.

Biochar

Biochar is a high-carbon and fine-grained residue that is currently produced through modern pyrolysis processes (direct thermal decomposition of biomass in the absence of oxygen and preventing combustion). Biochar may increase soil fertility of acidic soils (low pH soils), increase agricultural productivity and provide protection against some foliar and soil-borne diseases.

Benefits of Biochar

- **Carbon Sink:** The burning and natural decomposition of biomass releases large amounts of carbon dioxide and methane to the Earth's atmosphere. The biochar production process also releases CO_2 (up to 50% of the biomass); however, the remaining carbon content is stable indefinitely.
- **Soil Amendment:** Biochar is recognised as offering a number of soil health benefits. The extremely porous nature of biochar is found to be effective at retaining both water and water-soluble nutrients. Its presence in the earth can improve water quality, increase soil fertility, raise agricultural productivity and reduce pressure on old-growth forests.
- **Water retention:** Biochar is hygroscopic. Thus, it is a desirable soil material in many locations due to its ability to attract and retain water.

3.8 BIOFUEL

These fuel sources are directly or indirectly organic material, i.e., biomass (i.e., from plant materials and animal waste). Biofuel can exist in all three forms like solid, liquid or gas.

Primary Biofuel versus Secondary Biofuel

Primary biofuels include processed form of organic matter directly such as fuel wood, wood chips and pellets, which are used primarily for heating, cooking and electricity production. Secondary biofuels include the processed materials of biomass; for instance, liquid fuels like ethanol and biodiesel.

Generations of Biofuel

1. **First-Generation Biofuel:** Food-crop derivatives directly used for the generation of biofuels like starch, sugar, animal fats and vegetable oil. The most commonly used first-generation biofuel feed stocks are corn, wheat, sugarcane, sugar beets, rapeseed, peanuts, soya bean, etc.

   Ethanol Conversion Processes: Ethanol is produced by a wide variety of carbohydrate material via fermentation process. These raw materials can be: (a) Sugar-containing crops: Sugar cane, wheat, beet root, fruits, etc. (b) Starch-containing crops: Grains such as wheat, barley, rice, corn, etc., and root plants like potato, cassava. (c) Cellulosic biomass: Wood and wood waste, cedar, pine, etc., agricultural residues and fibres. We can blend alcohol (ethanol) with petrol or burn it in nearly pure form in slightly modified spark-ignition engines. Energy produced by 1 litre of ethanol is equivalent to two-thirds of the energy produced by 1 litre of petrol. The combustion performance is improved by blending process and the emission of carbon monoxide and sulphur dioxide is consequently lowered.

   Biogas (60% methane + 40% CO_2 + some rare gases), cutting wood, grass, agriculture waste etc., are also considered under first-generation biofuel.

2. **Second-Generation Extraction Technology:** Feedstock of the first-generation biofuels is used in production of second-generation biofuels. These are generally non-food crops (non-edible). All second-generation biofuels are not produced as a feedstock of the first-generation only, even a lot of plant cultivate is used as a direct biomass like – Switch grass, Jatropha, Pangomia.

   These are particularly lignocellulose feedstock, which tends to require several processing steps to obtain biofuel, like thermochemical conversion and biochemical conversion.

   (a) ***Thermochemical Conversion:*** Gasification and pyrolysis type of mechanisms are considered under this process (discuss in biomass gasification).

   (b) ***Biochemical Conversion:*** Different chemical reactions involved in the process of biofuel production, e.g., transesterification.

Note: Second-generation feedstock should grow on marginal land (not very productive land like food crop) because second-generation feedstock does not require a huge amount of water or fertiliser to grow. There are different examples of second-stage feedstock: Grasses (Switch grass, Myscanthus, Indian grass and others), biodiesel plants (Jatropha/Ratanjot, Pongamia, etc.), other seed crops (Cammelina, Palm Oil, Rape seed oil, etc.), waste vegetable oil and municipal solid waste (landfill gas, human waste, grass and yard clippings).

Lignocellulosic material can also be converted into ethanol by some enzymatic activity. The recent discovery of fungus Gliocladium roseum points towards the production of diesel from cellulose. Recently, neem seed is being used for biodiesel production.

3. **Third-Generation Biofuel:** This generation is also called as Algal oil or algoil, because a specific group of plant (Algae) is used for biofuel production. Some microalgae species like **Botryococcus braunii** and **Schizochytrium** can contain up to 80% of their dry weight of lipids. Some algae like **Dunaliella** and **Chlorella** are also good sources of lipid constituents. Through trans esterification processes, these lipid substances can be converted into biodiesel.

Why Algae for Biofuel (Biodiesel) Production?

- The fastest growing plants in the world are algae and unlike seasonal crops they can be grown throughout the year.
- Agriculture land or clean water is not required in algae farming, and hence it does not compete with food crops.
- It is difficult to compare one energy crop to another energy crop, however per hectare of farming of algae is around 10–100 times more productive than soyabean, palm, corn, jatropha.
- The entire biomass produced can be utilised in end products, which is not the case with other energy crops.
- Algal meal has a higher protein content than other animal feed product.

SPECIFICATION OF JATROPHA

Scientific name of this plant is *Jatropha curcas* and belongs to Euphorbiaceae family. This plant is the native of South America and Africa. Jatropha curcas is well adapted to **arid** and **semi-arid conditions.** With low fertility and moisture demand, it can grow on stony, gravelly or shallow and even calcareous soils.

Jatropha is grown well in low rainfall conditions (200 millimetres); however, it can also tolerate high rainfall (up to 1,200 millimetres) and hence it grows in a number of climatic zones in tropical and sub-tropical regions of the world and even in areas of low rainfall. Jatropha sheds most of its leaves, thereby reducing the transpiration loss and hence can stand long periods of drought. The annual temperature range tolerable to Jatropa is of 18–28.5°C. For seed germination, hot and humid climate is preferred. The flowers are induced in rainy season and fruits are borne in winter.

A multipurpose shrub or small size tree, Jatropha has significant importance due to its several industrial and medicinal uses. The various alkaloids contained in latex of Jatropha are 'Jatrophine', 'jatropham', 'jatrophone' and 'curcain', which bear anti-cancerous properties. The leaves of Jatropha contain galactogoue, rubefacient and anti-parasitic, which is used against scabies, paralysis, rheumatism and hard tumours. Seeds are aperient and used for dropsy, gout, paralysis and skin diseases. The oil is applied to hair as a growth stimulant, in Java. Other application include for sores on domestic livestock.

Jatropha have lipid substances that will convert into biodiesel through transesterification (TE) process in laboratory or industry.

- Unlike comparable crops, algae typically contain a sustainable amount of vested biomass, 100% of algal biomass can be utilised for creating new products.
- Jatropha takes 2–3 years for a commercial crop, whereas the algal form can start yielding within 2–3 days. While jatropha gives crop once a year, algae can give oil on a daily basis.

Note: The list of fuels derived from algae includes Biodiesel, Butanol, Gasoline, Methane, Ethanol, Vegetable Oil and Jet Fuel.

4. **Fourth-Generation Biofuel:** A combination of photovoltaic or inorganic water-splitting catalysts with metabolically engineered microbial fuel production pathways (Electro-biofuels/Microbial fuel cells – MFCs) has emerged to be powerful technology, enabling efficient production and storage of liquid fuels.

Note: Contribution of India in reduction of Greenhouse Gases (under UNFCC, COP-21 Meeting)

Intended Nationally Determined Contributions (INDCs) Pledged by India in COP 21 (Paris Convention):

1. Reduction in emission intensity by 33–35% by 2030 compared to 2005 levels.
2. Production of 40% of electricity from non-fossil fuel-based energy resources by 2030, with help of international community in terms of technology transfer and low-cost finance.
3. Creation of additional carbon sink of 2.5–3 billion tonnes of carbon dioxide, equivalent through additional forest and tree cover by 2030.
4. Development of robust adaptation strategies for agriculture, water and health sectors.

(Refer Infographic – Generation of Biofuel)

3.8.1 Ethanol

Ethanol, or ethyl alcohol, is a biofuel, that has several uses.

- At 95% purity, it is called rectified spirit and is used as the intoxicating ingredient in alcoholic beverages.
- Ethanol is basically alcohol of 99%-plus purity, which can be used for blending with petrol.
- Produced mainly from molasses, a by-product of sugar manufacture.

Benefits of Ethanol Blending

- Reduction in import dependency.
- Support to agricultural sector.
- Environmental friendly fuel.
- Additional income to farmers.

About Ethanol Blended Petrol (EBP) Programme

- Launched in 2003 on pilot basis.
- The aim is to promote the use of alternative and environmental friendly fuels.
- Implemented by the Ministry of Oil Marketing Companies (OMCs).

TYPES OF ALTERNATIVE FUELS

1. **Ethanol:** Primarily alcohol is produced by fermentation and further distillation of crops like corn, barley, sugarcane bagasse, wheat, etc. It is blended with gasoline to increase octane level and improve emission quality.
2. **Natural Gas:** It is already in use in several countries through utilities that provide natural gas to homes and it burns clean. Cars and trucks with specially designed engines run through natural gas with less harmful emissions.
3. **Propane:** The other name of propane is Liquefied Petroleum Gas (LPG); it is a by-product of crude oil refining and natural gas processing. It is widely used as cooking gas and a popular alternative fuel.
4. **Biodiesel:** It is one of the fuels whose source is always renewable. It can be produced from vegetable oils or animal fats and also the cooking wastes of restaurants. Vehicle engines can be converted to run by pure biodiesel and it is also blended with petroleum diesel to run in modified engines also.
5. **Methanol:** One of the present day important alternatives fuels – much attention has been paid on cost-effective production of methanol, which can be used as a source of alternative fuel. It is an important raw material for production of fuel cell grade hydrogen to run hydrogen powered vehicles.
6. **Electricity:** Electricity can be used as transportation alternative fuel for battery-powered electric and fuel-cell vehicles.
7. **Hydrogen:** It can be mixed with natural gas to create an alternative fuel which can be used in some types of internal combusting engines. Hydrogen is the fuel for fuel-cell vehicles and is produced by the petrochemical reaction.
8. **P-Series Fuels:** These are blends of ethanol, LNG and methyltetrahydrofuran (MeTHE) in different proportions. The P-Series alternative fuels are clear and have high octane number with flexibility of choice of vehicles. It has the option of addition to normal gasoline.

BIOFUEL

The fuel sources are directly or indirectly **organic material** i.e. Biomass (i.e. from plant materials and animal waste).

Biofuel can exist **in all three forms** i.e.

- **Solid**
- **Liquid**
- **Gas**

Generations of Biofuel

1st Gen Biofuel

- **Food Crops derivatives are directly** used for the generation of biofuels like starch, animal fats and vegetable oil.
- Feedstocks: **Corn, Wheat, Sugarcane, Sugar, Beets, Rapeseed, Peanuts, Soybean etc.**
- **It has** high carbon content (Net Carbon Positive).
- Net Energy Negative.

2nd Gen Biofuel

- **Feedstock of 1st Gen Biofuels is used in production of 2nd Gen Biofuels. These are generally** non-food Crops.
- Feedstocks: **Switch Grass, Jatropha and** Pangomia.
- **These are particularly** lignocellulose feed stock, **which tends to** require several processing steps to obtain biofuel.
- **Greenhouse gas content is comparatively less than that in 1st Gen.**
- Potential to be Net Energy Positive.

3rd Gen Biofuel

- **3rd Generation is called as** Algal Oil or Algoil **because a specific group of plant (Algae) is used for biofuel preparation.**
- **Some microalgae species like** Botryococcus Braunii **and** Schizochytrium **can contain upto 80% of their dry weight of lipids**
- **It is** Carbon Neutral in nature, **(CO_2 Emitted = CO_2 Sequestrated) and** Net Energy Positive.
- It is fastest growing of all biofuel sources.
- Resilient organisms that can be grown from sunlight, CO_2 and brackish water.

4th Gen Biofuel

- **The 4th Generation biofuels combine genetically engineered feedstock with genomically synthesized microorganisms, such as cyanobacteria, to efficiently generate bioenergy, and they are made using nonarable land similar to third-generation biofuels.**
- **Genetic Engineering of organisms for efficient production of biofuels.**
- **Aim to be** Carbon Negative by creating artificial carbon sinks. **And it is** Net Energy Positive.

Need

- India is the third largest consumer of energy in the world after China and the United States.
- India is dependent on imports for about 82.1% of its crude oil requirement and to the extent of about 44.4% in case of natural gas.
- India is expected to need 10 billion litres of ethanol annually to meet the 20% blending target in 2030 if petrol consumption continues to grow at the current pace. At present, the capacity stands at 1.55 billion litres a year.

Concerns and Challenges

- Consistent shortfall in supply of ethanol in the past, mainly on account of the cyclical nature of the sugarcane harvests in the country.
- Lack of an integrated approach in the EBP across its value chain.

Way Ahead

- The National Policy on biofuels has set a target of 20% blending of biofuels, both for bio-diesel and bioethanol. This will require an integrated approach in the Ethanol Blending Programme (EBP). The time is ripe for a clear and consistent policy and administrative framework in the programme implementation for the success of EBP.

3.8.2 Methanol-Blending in Petrol

The world over, methanol is being looked upon as a viable alternative fuel. The government of India's NITI Aayog has also drawn out a road map to replace 10% of crude imports by 2030 with Methanol. It has set up an apex committee and five task forces for carrying out R&D activities and developing a road map for implementing the methanol economy in India.

Methanol is a clear and colourless liquid produced from natural gas, coal biomass. It is a clean burning fuel that can replace petrol and diesel. It burns efficiently in all internal combustion engines causing almost zero pollution. Its gaseous version – Dimethyl Ether or DME – can even be blended with LPG.

India imported 212.7 million tonnes of crude oil in 2016–17. It is estimated that a 15% Methanol blending can result in replacement of around 31.9 million tonnes of crude oil, which would in turn lead to significant foreign exchange savings for the country. At least 20% diesel consumption can be reduced in the next five to seven years resulting in a savings of ₹26000 crores annually; ₹6000 crores can be annually saved from reduced bill in LPG in the next three years, and when blended with gasoline it will further reduce our fuel bill by at least ₹5000 crores annually in the next three years.

The use of Methanol and DME as fuel has increased significantly during the last few years with the Methanol demand growing at 6–8% annually. Methanol accounts for almost 9% of transport fuel in China. Israel and Italy have adopted the **Methanol 15% (M15)** blending programme with petrol. Japan and Korea have extensive Methanol & DME usage and Australia has adopted GEM fuels (Gasoline, Ethanol and Methanol) and blends almost 56% Methanol.

In India as per the plan prepared by the NITI Aayog, 20MT of Methanol can be produced every year by 2025 using coal, gas and biomass. NITI Aayog's road map for Methanol Economy envisages utilisation of Methanol as well as DME in transportation – rail, road, marine and defence, industrial boilers, diesel gensets, power generation, mobile towers and domestic cooking fuel are other applications.

It is hoped that the advent of the Methanol Economy in the country would be a major step towards combating air pollution, reducing greenhouse gas emissions and promoting huge foreign exchange savings.

- A study, in which **methanol (M-15) was blended with petrol and used in the existing BS-IV standard** cars, found that the carbon dioxide emission had reduced substantially.

Methanol as an Alternative Fuel

- Methanol is a promising fuel as it is **clean, cheaper than fossil fuels and a good substitute for heavy fuels. India imports methanol from Saudi Arabia and Iran at present.**
- Across the world, methanol is emerging as a clean, sustainable transportation fuel of the future.

Why Methanol?

- Methanol can be used as an **energy producing fuel, transportation fuel and cooking fuel,** cutting down India's oil import bill by an estimated 20% over the next few years. Unlike CNG, using methanol as a transportation fuel would require minimal alteration in the vehicles.

- Methanol is **a clean-burning fuel** that **produces fewer smog-causing emissions – such as sulphur oxides (SO_x), nitrogen oxides (NO_x) and particulate matter** – and can improve air quality and related human health issues.
- Methanol is **most commonly produced on a commercial scale from natural gas.** It can also be produced from renewable sources such as biomass and recycled carbon dioxide.
- As a high-octane vehicle fuel, **methanol offers excellent acceleration and power.** It also improves vehicle efficiency.

Way Ahead

- The Concept of 'Methanol Economy' is being actively pursued by China, Italy, Sweden, Israel, United States, Australia, Japan and many other European countries. 10% of fuel in China in transport sector is Methanol.
- Methanol Economy, if adopted by India can be one of the best ways to mitigate the environmental hazards of a growing economy. NITI Aayog is preparing a road map for a full-scale implementation in the near future.

3.9 'FLEX-FUEL' VEHICLES (FFV)

- An FFV is a modified version of vehicles that could **run both on gasoline and doped petrol with different levels of ethanol blends.**
- FFVs will allow vehicles to use all the blends and also run on unblended fuel.
- FFVs have compatible engines to run on more than 84% ethanol blended petrol.
- Union Government had issued new guidelines for use of **FFVs using flex engines**.
- The guidelines will specify engine configuration and other changes required in vehicles to conform to stipulated changes in fuel mix.
- The **central government has released an expert committee report** on the **Roadmap for Ethanol Blending in India by 2025.**
- The roadmap proposes **a gradual rollout of ethanol-blended fuel** to achieve E10 fuel supply by April 2022 and phased rollout of E20 from April 2023 to April 2025.

About

- It is one of the principal biofuels, which is naturally produced by the fermentation of sugars by yeasts or via petrochemical processes such as ethylene hydration.
- These are currently being used successfully in Brazil, giving people the option to switch fuel (gasoline and ethanol) depending on the price and convenience.
- For India, FFVs will present a different advantage as they will allow vehicles to use different blends of ethanol-mixed petrol available in different parts of the country.

Blending Target

- The Government of India has advanced the target for 20% ethanol blending in petrol (also called E20) to 2025 from 2030.
- Currently, 10% of ethanol is blended with petrol in India.

Benefits

- Reduces the oil import bill.
- Can save the country USD 4 billion (₹30,000 crore) per annum.
- Benefits the sugarcane farmers.
- Encourages use of water-saving crops, such as maize, to produce ethanol, and production of ethanol from non-food feedstock.
- Decreases emissions such as carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NO_x).

Disadvantages/Challenges of using FFVs

1. **Customer acceptance** will be a major challenge since the cost of ownership and running cost are going to be very high compared with 100% petrol vehicles.
2. **Running cost** (due to lower fuel efficiency) will be higher by more than 30% when run with 100% ethanol (E100).
3. **Flex Fuel Engines cost more** as ethanol has very different chemical properties than petrol. Ethanol has very low (40%) Calorific value as compared to Gasoline, very high latent heat of vaporisation causing cooling of charge/combustion, etc.

4. **Ethanol also acts as a solvent and could wipe out the protective oil film inside the engine** thereby causing wear and tear.

Possible Challenges that Might be Faced During the Implementation of the Program

- High cost of the flex fuel engines.
- Running cost will be higher due to the lower fuel efficiency.
- Acceptance by the customers.
- Ethanol acts as a solvent and could wipe out the protective oil film inside the engine thereby causing wear and tear.

3.10 NATIONAL POLICY ON BIOFUELS 2018

The Union Cabinet, chaired by the Prime Minister Shri Narendra Modi, has approved National Policy on Biofuels – 2018.

Salient Features

1. The Policy categorises biofuels as 'Basic Biofuels' viz. First-Generation (1G) bioethanol and biodiesel and 'Advanced Biofuels' – Second-Generation (2G) ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third-Generation (3G) biofuels, bio-CNG, etc., to enable extension of appropriate financial and fiscal incentives under each category.
2. The policy expands the scope of raw material for ethanol production by allowing use of sugarcane juice, sugar containing materials like sugar beet, sweet sorghum, starch containing materials like corn, cassava, damaged food grains like wheat, broken rice, rotten potatoes, unfit for human consumption for ethanol production.
3. Farmers are at a risk of not getting appropriate price for their produce during the surplus production phase. Taking this into account, the policy allows use of surplus food grains for production of ethanol for blending with petrol with the approval of National Biofuel Coordination Committee.
4. With a thrust on Advanced Biofuels, the policy indicates a viability gap funding scheme for 2G ethanol biorefineries of ₹5000 crore in 6 years in addition to additional tax incentives, higher purchase price as compared to 1G biofuels.
5. The policy encourages setting up of supply chain mechanisms for biodiesel production from non-edible oilseeds, used cooking oil, short gestation crops.
6. Roles and responsibilities of all the concerned Ministries/Departments with respect to biofuels has been captured in the policy document to synergise efforts.

Expected Benefits

- **Reduce Import Dependency:** One crore litres of E10 saves ₹28 crore of forex at current rates. The ethanol supply year 2017–18 is likely to see a supply of around 150 crore litres of ethanol which will result in savings of over ₹4000 crore of forex.
- **Cleaner Environment:** One crore litre of E-10 saves around 20,000 tons of CO_2 emissions. For the ethanol supply year 2017–18, there will be lesser emissions of CO_2 to the tune of 30 lakh tons. By reducing crop burning and conversion of agricultural residues/wastes to biofuels there will be further reduction in greenhouse gas emissions.
- **Health Benefits:** Prolonged reuse of Cooking Oil for preparing food, particularly in deep-frying is a potential health hazard and can lead to many diseases. Used cooking oil is a potential feedstock for biodiesel and its use for making biodiesel will prevent diversion of used cooking oil in the food industry.
- **MSW Management:** It is estimated that, annually 62 MMT (Million Metric Tonne) of Municipal Solid Waste gets generated in India. There are technologies available which can convert waste/plastic, MSW to drop-in fuels. One ton of such waste has the potential to provide around 20% of drop-in fuels.
- **Infrastructural Investment in Rural Areas:** It is estimated that, one 100 klpd (kilo litres per day) biorefinery will require around ₹800 crore capital investment. At present Oil Marketing Companies are in the process of setting up twelve 2G biorefineries with an investment of around ₹10,000 crore. Further, addition of 2G biorefineries across the country will spur infrastructural investment in the rural areas.
- **Employment Generation:** One 100 klpd 2G bio refinery can contribute 1200 jobs in plant operations, village level entrepreneurs and supply chain management.

- **Additional Income to Farmers:** By adopting 2G technologies, agricultural residues/waste which otherwise are burnt by the farmers can be converted to ethanol and can fetch a price for these waste if a market is developed for the same. Also, farmers are at a risk of not getting appropriate price for their produce during the surplus production phase. Thus conversion of surplus grains and agricultural biomass can help in price stabilisation.

(Refer Infographic – National Policy on Biofuel 2018)

WORLD BIOFUEL DAY

- **World Biofuel Day is observed every** year on 10th August.
- **Aim:** to create awareness about the importance of non-fossil fuels as an alternative to conventional fossil fuels and to highlight the various efforts made by the Government in the biofuel sector.
- **Theme 2022:** 'Biofuels for Sustainability and Rural Income'.
- On this day in 1893, Sir Rudolph Diesel (inventor of the diesel engine) for the first time successfully ran mechanical engine with peanut oil.
- His research experiment had predicted that vegetable oil is going to replace the fossil fuels in the next century to fuel different mechanical engines.
- In India, Ministry of Petroleum and Natural Gas (MoPNG) celebrates the World Biofuel Day every year.

Stardust 1.0, the first rocket to run on biofuel

Stardust 1.0 was launched on 31 January 2021 from Loring Commerce Centre in Maine, US.

- It has become **the first commercial space launch powered by biofuel,** which is non-toxic for the environment as opposed to traditionally used rocket fuels.
- Stardust 1.0 is a launch vehicle suited for student and budget payloads.

3.11 URJA SANGAM 2015/PAHAL

- The Prime Minister, Shri Narendra Modi, urged well-to-do sections of the Indian society to voluntarily give up LPG subsidy, for benefiting the poorer sections of society. During the inaugural address at global energy summit – **'Urja Sangam 2015'** – in New Delhi.
- **'Give it up'** campaign was launched by the Prime Minister for voluntarily giving up LPG subsidy. The Union Government targets to extend the reach of Piped Natural Gas (PNG) to 1 crore houses in the next five years.
- On the occasion of the platinum jubilee of India's independence, the Prime Minister called for enhancement of domestic production, which could reduce the energy import load of the country by at least 10% till 2022. He said that **PAHAL – the world's largest cash subsidy transfer programme** in the world, enabling transfer of LPG subsidy directly into bank accounts had consequently led to the elimination of leakages, and curbing corruption.
- He also mentioned deregulation of diesel prices, ethanol and ethanol-blended petrol in order to assist sugarcane farmers, promotion of bio-diesel and extension of the gas grid in eastern India, as some other major initiatives of the Government. According to the Prime Minister, over the next five years, the Union Government aims to extend piped natural gas (PNG) to one crore houses.

3.12 UJJWALA YOJANA

It was launched by the PM from Ballia on 1 May 2016. The scheme ideated to provide 8 crore cooking gas connections to Below Poverty Line families over the next three years (2016–2019). The scheme provides financial support for each LPG connection to the BPL household. The households will be identified in consultation with the state governments and UTs.

About Pradhan Mantri Ujjwala Yojana (PMUY)

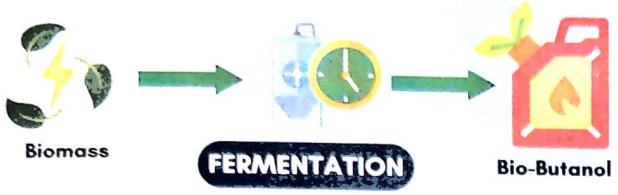
- Under the scheme, an adult woman member of a below poverty line family **identified through the Socio-Economic Caste Census** (SECC) is given a deposit-free LPG connection with **financial assistance of ₹1,600 per connection** by the Centre.
- Eligible households will be identified in consultation with state governments and union territories. **The scheme is being implemented by the Ministry of Petroleum and Natural Gas.**

Some objectives of the scheme are:

- Empowering women and protecting their health.
- Reducing the serious health hazards associated with cooking based on fossil fuel.

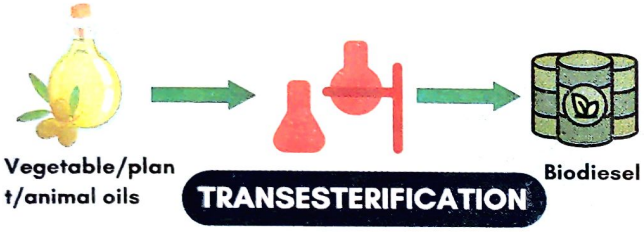
SOME OTHER BIOFUELS

Biobutanol



Biogas

Biodiesel



Bioethanol

NATIONAL POLICY ON BIOFUEL 2018

An indicative target of 20% blending of ethanol in petrol by 2025-26 and 5% blending of biodiesel in diesel is proposed by 2030.

With a thrust on Advanced Biofuels, the Policy indicates a viability gap funding scheme for 2G ethanol bio refineries of Rs.5000 crore in 6 years in addition to additional tax incentives, higher purchase price as compared to 1G biofuels.

Categorization of biofuels into Basic Biofuels
1st Gen - Bioethanol, Biodiesel and Advanced Biofuels
2nd Gen - Ethanol, Drop-in-fuels and Algae based
3rd Gen - Bio-CNG

Increase scope of raw material for ethanol procurement by encouraging intermediate (B-Molasses), sugarcane Juice, other sugar containing materials and damaged as well as surplus food grains.

Develop National Biomass repository by conducting appraisal of biomass across the Country.

Biodiesel production to be encouraged from non edible oilseeds, used cooking oil, short gestation crops and development of supply chain mechanisms.

Thrust on research, development and demonstration in the field of biofuel feedstock production, advanced conversion technologies from identified feedstock.

Setting up of National Biofuel Coordination Committee (NBCC) under Ministry of Petroleum & Natural Gas and Working Group on Biofuels.

- Reducing the number of deaths in India due to unclean cooking fuel.
- Preventing young children from significant number of acute respiratory illnesses caused due to indoor air pollution by burning the fossil fuel.

What makes LPG adoption necessary?

- A large section of Indians, especially women and girls, are exposed to severe **household air pollution** (HAP) from the use of solid fuels such as biomass, dung cakes and coal for cooking. A report from **the Ministry of Health & Family Welfare places HAP as the second leading risk factor contributing to India's disease burden.**
- According to the World Health Organisation, **solid fuel use is responsible for about 13% of all mortality and morbidity in India** (measured as Disability-Adjusted Life Years), and causes about 40% of all pulmonary disorders, nearly 30% of cataract incidences, and over 20% each of ischaemic heart disease, lung cancer and lower respiratory infection.

Kerala is now set to become the **first smoke-free state in the country with public sector oil companies eyeing 100% LPG penetration here.**

- LPG is being supplied beyond commercial considerations with the **Pradhan Mantri Ujjwala Yojana initiated by the Ministry of Petroleum.**

Ujjwala 2.0

Prime Minister Shri Narendra Modi had launched Ujjwala 2.0 by handing over LPG connections, at Mahoba Uttar Pradesh on 10th August, 2021 via video conferencing. During the event, the Prime Minister interacted with beneficiaries of the Ujjwala and also addressed the nation.

The Journey from Ujjwala 1.0 to Ujjwala 2.0

During Ujjwala 1.0, a target was set to provide LPG connections to 5 crore women members of BPL households. Subsequently, the scheme was expanded in April 2018 to include women beneficiaries from seven more categories (SC/ST, PMAY, AAY, Most backward classes, tea garden, forest dwellers, Islands). Also, the target was revised to 8 crore LPG connections. This target was achieved in August 2019, seven months ahead of the target date.

In the Union budget for FY21–22, provision for an additional one crore LPG connection under the PMUY scheme was announced. These **one crore additional PMUY connections (under Ujjwala 2.0) aim to provide deposit-free LPG connections to those low-income families who could not be covered under the earlier phase of PMUY.**

3.13 PRADHAN MANTRI URJA GANGA

GAIL (Gas Authority of India Limited) is a pioneer in city gas distribution in India. 'Petroleum Ministry' launched a ₹1750 crore city gas distribution project between Bhubaneshwar and Cuttack on March 2017, taking a big step towards linking of eastern India to the natural gas grid connection through Jagdishpur-Haldia and Bokaro-Dhamra Natural Gas Pipeline (JHBDPL).

The gas pipeline project aims to **provide piped cooking gas to residents of Varanasi** and later to millions of people in states like **Bihar, Jharkhand, West Bengal and Odisha.** The government estimates that around 5 lakh gas cylinders will be sent to rural areas annually.

According to GAIL, with the Urja Ganga project, **20 lakh households will get PNG connections.** The project is said to be a major step towards collective growth and development of the Eastern region of India. GAIL has built a network of trunk pipelines covering the length of around 11,000 km. With Urja Ganga project, this number will further increase by 2540 km.

Northeast Gas Pipeline Grid Project

Five public sector oil and natural gas companies have signed the joint venture agreement to implement the ₹6000 crore gas pipeline grid project in Northeast.

The five companies are Indian Oil Corporation Limited (IOCL), ONGC, GAIL, Oil India Limited and Numaligarh Refinery Limited (NRL).

With the signing of the agreement the joint ventures company will develop, build, operate and maintain the natural gas pipeline grid.

- The proposed gas pipeline grid will connect Guwahati to the major Northeast cities and major load centres.
- The project is being implemented under **Prime Minister Narendra Modi's ambitious Urja Ganga Gas Pipeline Project.**

- Besides connecting all the state capitals in the region, the pipeline will also connect with the National Gas Grid through Barauni – Guwahati Gas Pipeline, which is being laid by GAIL.
- From Guwahati, the pipeline will extend to Numaligarh, Dimapur, Kohima and Imphal in one direction; Shillong, Silchur, Aizwal and Agartala in the second direction and to Itanagar in the third direction. Gangtok will be connected from Siliguri from the gas pipeline of GAIL coming from Barauni to Guwahati.

KEY NOTES

- The proposed gas pipeline grid will connect Guwahati to the major Northeast cities and major load centres.
- The project is being implemented under ambitious Urja Ganga Gas Pipeline Project.
- Besides connecting all the state capitals in the region, the pipeline will also connect with the National Gas Grid through Barauni–Guwahati Gas Pipeline, which is being laid by GAIL.
- The pipeline will enable the supply of piped cooking gas to households and CNG to automobiles, besides fuel to industry.
- The 1656-km-long natural gas pipeline NEGG (North East Gas Grid) Project has set a target of completing 70% of its works in the fiscal concluding by 31 March 2023, and the entire project by 31 March 2024.

3.14 RURAL ELECTRIFICATION

As per 2011 census, nearly 80% population of the country stays in the rural areas, including 167.8 million families. The backbone of the rural economy is often seen in rural electrification. The four facets of rural electrification are:

- Establishment of rural electrification infrastructure, thereby providing household connectivity.
- Desired power quality to be adequately supplied.
- Supplying electricity at reasonable tariff.
- Effective and efficient provision of environmentally friendly, clean and sustainable power.

Note: As per the recent studies, there is lack of access to grid electricity to around 58.5 million households. Nearly 55.8% and 67.2 % of the total households were electrified in the years 2001 and 2011, respectively. In the past, the electrification process was at a sluggish pace due to uneven focus on policy. In addition to that, various other issues like concerns of political economy and the organisation and institutional levels restrained are also responsible towards the country's slow development of electrification in rural areas.

3.14.1 Rural Electrification Policy 2005

The key for accelerating rural development is seen in rural electrification and hence, provision of electricity is essential to cater for many requirements of life. As per the National Electricity Policy, supply of electricity to all areas including rural, as mandated in Section 6 of Electricity Act, marks the key development objective of the power sector. This National Policy for Rural Electrification has been prepared and framed up through an extensive consultative process undertaken by the Ministry of Power.

Aims of the Policy

- Provision of access to electricity to all households by the year 2009.
- Quality and reliable power supply at reasonable rates.
- Minimum lifeline consumption of 1 unit per household per day by 2012.

However, these targets are yet to be achieved. Based on the certificate issued by Gram Panchayat with certain properties, the REP has changed the definition of electrified villages. For rural electrification to be achieved in a sustainable way, a massive focus on creation on income generation activities has to be given to boost the rural economy.

Approach to Rural Electrification

- Grid connectivity is the normal way of electrification of villages.
- For villages with no possibility of grid connectivity, offgrid solutions based on standalone system may be taken up for electricity supply.
- Decentralised distributed generation facilities, along with local distribution network, be it through conventional or non-conventional methods of electricity generation.
- State government should, within six months, prepare and notify a Rural Electrification Plant to achieve goal of providing access to all households.
- Mapping and detailed electrification delivery mechanism should be deployed to rural electrification plan.

Note: Rural Electrification Corporation Limited (REC), a Government of India enterprise under Ministry of Power, is the nodal agency to implement Rural Electrification Programme.

3.14.2 Rajiv Gandhi Grameen Vidyutikaran Yojna (RGGVY)

RGGVY was launched by the central government on 4 April 2005, for attaining the National Common Minimum Programme (NCMP) objective of providing access to electricity to all households in the country in 5 years. The scheme aimed at electrification of over 1 lakh un-electrified villages and providing electricity connection to 2.34 crore rural households approximately. The estimated cost was ₹51,000 crores. A village or hamlet with a population of 100 or more is eligible for this scheme. This scheme is being implemented mostly to provide benefits to households below poverty line (BPL) through a free connection but chargeable consumption of power. Under this scheme, central government provides 90% of grant and 10% as a loan, which is provided by REC (Rural Electrification Corporation) to all state governments. The REC is the main nodal working agency for this scheme.

Aim

- Electrifying every village as well as habitation, according to new guidelines.
- Proper electricity to every rural household.
- To offer electricity connection to every BPL family without charge.

Conditions and Implementation Methodology

- Main work is preparation of various district boards for proper execution.
- Proper involvement of public sector.
- Daily supply of 6–8 hours of proper electricity in areas of RGGVY.
- Outline electronic fund transfer directly to contractor account.
- Three-tier system of quality monitoring management.

3.14.3 Deen Dayal Upadhyaya Gram Jyoti Yojna (DDUGJY)

DDUGJY is a Government of India scheme designed to give continuous power supply to rural India as one of a key initiative of the Modi Government. This scheme will replace existing RGGVY. This was launched on 25 July 2015 in Patna by PM Modi. This is one of the major programmes of the ministry of power and will facilitate 24 × 7 power supply.

It draws its inspiration from the similar pioneering scheme implemented by the Government of Gujarat. This will enable to initiate much awaited reform in rural areas. It focuses on feeder separations (rural household and agriculture) and strengthening of sub-transmission and distribution infrastructure. It also includes metering at all levels on rural areas.

Particularly, there are two major components in DDUGJY, i.e., **providing power till 2019 to all** and **feeder separation,** which were not included in the RGGVY. The government has started undertaking different measures and also working in the direction of supplying power to the country's last standing mile. The target of the Government is the completion of all electrification of villages by the year 2019.

Objectives

- Provide electrification to all villages.
- Feeder separation to ensure sufficient power to farmer and regular supply to other consumer.
- Sub-transmission and distribution framework to be improved to enhance quality and reliability of the supply.
- Metering to reduce losses.

Benefits

- All villages and households shall be electrified.
- Increased agriculture yield.
- Business of small and household enterprise shall grow consequently.
- Improvement in health, education, ATM services.
- Improvement in accessibility to radio, telephone, mobile, etc.
- Betterment in social security due to availability of electricity.
- Accessibility of electricity to schools, panchayats, etc.
- Rural areas shall get increased opportunities for comprehensive development.

3.14.4 Saubhagya: Sahaj Bijli Har Ghar Yojana

Union Ministry of Power had launched Pradhan Mantri Sahaj Bijli Har Ghar Yojana on 25 September 2017 (Birth ceremony of Pt. Deen Dayal Upadhaya). Its aim is to achieve universal household electrification (to all rural and urban poor households) in all parts of country by providing electricity connectivity. These households

will be identified under Socio-Economic and Caste Census (SECC) data 2011.

Rural Electrification Corporation Limited (REC) is the nodal agency for operationalization of Saubhagya scheme throughout India. For this accelerated implementation, household survey will perform with the help of Mobile App. Public institutions/Gram Panchayat in rural areas will be authorised to collect application and documents. They will distribute and collect revenue in consultation with Panchayat Raj Institutions (PRIs) and Urban Local Bodies (ULBs).

For APL (Above poverty line) families, ₹500 will be payable in 10 equal monthly instalments but BPL cardholders will get free electricity connections.

In remote and inaccessible areas, solar power packs of 200 to 300 watts with battery will be provided. It will also comprise of 5 LED lights, 1 DC fan, 1 DC power plug with all Repair and Maintenance (R and M) for next 5 years.

The total outlay of scheme is ₹16,320 crore while Gross Budgetary Support (GBS) is ₹12,320 crore. This is a central government scheme. A total of 2.817 crore households were electrified since the launch of SAUBHAGYA, up to 31 March 2021. Thereafter, some States again reported that 11.84 lakh households remain to be electrified. Electrification of these households was again sanctioned, till date, a total 2.86 crore households have been electrified (last update till 15 December 2022).

This scheme will have many outcomes like to improve health services, education services, various economic activities and jobs, improved quality of life especially for women, everyone can easily connect through radio, television, mobiles, etc., and also environmental upgradation (due to complete replacement of kerosene for lighting purposes).

3.15 UJWAL DISCOM ASSURANCE YOJANA (UDAY)

UDAY is the financial turnaround and revival package for power distribution companies of India (DISCOMs) and more importantly offers a sustainable permanent solution to the problem. It is a path breaking reform for realising the Prime Minister's vision of affordable and accessible 24 × 7 power for all. It is another decisive step, further being the landmark strides made in the power sector over the past years. Financially stressed DISCOMs could not function adequately, because the legacy issues trapped the DISCOMs in a vicious cycle with operational loses being funded by debt. A rise of vibrant and efficient DISCOMs through a permanent resolution of past as well as potential future issues of the sector is assured by UDAY. The scheme empowers DISCOMs to breakeven in the next 2–3 years by different initiatives.

Four Initiatives of Scheme

1. Operational efficiencies of DISCOMs improved.
2. Cost of power reduced.
3. Reduction in interest cost of DISCOMs reduced.
4. Financial disciplines on DISCOMs enforced, through alignment with state finances.

UDAY is a shining example of the utilisation of the best principles of cooperative and competitive federalism is being demonstrated by UDAY and has been evolved through discussion at highest levels with multiple states.

Features

- State shall take over 75% of DISCOM debt on 30 September 2015. 50% DISCOM debt shall be taken over in 2015–16 and 25% in 2016–17.
- Government of India will not include debt taken over by states in calculation of fiscal deficit in financial years 2015–16 and 2016–17.
- States will issue non-SLR in market/FIs/Bank holding DISCOM debt.
- DISCOM debt not taken by state shall be converted to loan with interest rate not more than bank's base rate of .01%.
- States shall take over future losses of DISCOM.
- States accepting UDAY and performing as per it will be given additional funding through Deen Dayal Upadhyaya Gram Jyoti Yojana, Integrated Power Development Scheme (IPDS) and Power Sector Development Fund (PSDF).
- This scheme was announced by Minister of State of Power, Coal and New Renewable Energy in November, 2015.
- Scheme is under optional basis for states to join, and till now 31 states/UT have joined this scheme. Mizoram being the 27th state to join.

3.15.1 Revamped Distribution Sector Scheme

The scheme has been recently launched by the Government of India **for better operations and**

financial sustainability of all DISCOMs. RDSS sanctions 20.46 crores pre-paid smart consumers meters, 54 lakh smart DT meters and 1.98 lakh smart feeder meters (last updated till 9 February 2023).

Highlights of the Scheme

- It is **a reforms-based and results-linked scheme.**
- It seeks **to improve the operational efficiencies and financial sustainability** of all DISCOMs/Power Departments excluding Private Sector DISCOMs.
- The scheme envisages the provision of **conditional financial assistance** to DISCOMs for strengthening supply infrastructure.
- The **assistance will be based on meeting pre-qualifying criteria** as well as upon the achievement of basic minimum benchmarks by the DISCOM.
- The scheme involves **a compulsory smart metering ecosystem** across the distribution sector – starting from electricity feeders to the consumer level, including in about 250 million households.
- The Scheme also focuses on funding for feeder segregation for unsegregated feeders.
- The Scheme has **a major focus on improving electricity supply for the farmers and for providing daytime electricity** to them through solarisation of agricultural feeders.

Implementation

- Nodal agencies for the scheme's implementation are **Rural Electrification Corporation (REC)** Limited and Power Finance Corporation (PFC).

Objectives of the Scheme

1. Reduction of average aggregate technical and commercial loss to pan-India levels of 12–15% by 2024–25.
2. Narrow the deficit between the cost of electricity and the price at which it is supplied to zero by 2024–25.
3. Developing institutional capabilities for modern DISCOMs.
4. Improvement in the quality, reliability and affordability of power supply to consumers through a financially sustainable and operationally efficient distribution sector.
5. These workers would only be required to submit a self-declaration of their residential address to get the gas connection.

3.16 UNNAT JYOTI BY AFFORDABLE LEDS FOR ALL (UJALA)

The Union Government has also initiated the nationwide programme for Home and Street LED-based Lighting, so as to conserve energy through the reduction of energy consumption. Subsequently, Energy Efficiency Services Ltd., a Government organisation, has launched the scheme for distribution of LED bulbs under **Domestic Efficient Lighting Programme (DELP)** in the year March 2015. Thereafter, in the year March 2016, this scheme got a fresh face and name termed as 'UJALA'.

The scheme's main objective is the promotion of efficient lighting, awareness enhancing on the usage of the equipment which efficiently reduces bills and aid in the environment preservation. Under this scheme, there is distribution of LED bulbs in a phased manner from the year March 2015. At present, the DELP scheme is continuing in the country's nine states – Uttarakhand, Himachal Pradesh, Andhra Pradesh, Jharkhand and Karnataka. Till 28 June 2016, there is distribution of around 123 million LED bulbs, which is being equivalent to energy saving of approximately 43 million kilowatts hour per day and further shunning away of peak demand of 3205 megawatts.

GRAM UJALA

Under this programme **Convergence Energy Services Limited (CESL)**, a wholly owned subsidiary of Energy Efficiency Services Limited (EESL), will distribute high quality LED bulbs, at an affordable cost of 10 rupees per bulb in rural areas.

Implementation

7-watt and 12-watt LED bulbs with 3 years warranty will be given to rural consumers against submission of working incandescent bulbs.

- Each household will get up to 5 LEDs.
- Participating rural households will also have metres installed in their houses to account for usage.

Financing Mechanism

- The programme will be financed entirely through carbon credits and will be the first such programme in India.
- The revenue earned from carbon credits will contribute ₹60 per LED bulb piece, with the balance ₹10 to be paid by the rural consumer.

3.17 CHALLENGES BEHIND RURAL ELECTRIFICATION

Rural electrification faces a lot of challenges. The rural electrification promotion on the basis of **grid extension is facing main obstacles during DDUGJY and various different programmes,** such as high grid-extension cost and lesser recovery subjected to highly subsidised tariff, low tariff collection level amounting to return in a negative form, lack of rationing of power-based supply and high costs of maintenance and operation. The sustainable rural electrification achievement is necessary by the way of focusing on creation of activities of income generation, which enhances the economy in rural areas. These affordable services, in turn, will be helpful for the rural households and further the masses are ready to reimburse for those services, which are sustainable and wealthy. The National Solar Mission should visualise on the connectivity of micro mini grids with conventional grids and also should not lose its focus on rural electrification.

The programme of rural electrification should be focussed on sustainable economic development of the rural communities. Henceforth, the rural electrification scheme must be a part of overall agenda of rural development and should be linked with various other social schemes.

3.18 'NELP' AND 'HELP'

3.18.1 'NELP' (New Exploration Licensing Policy)

National Exploration License Policy in 1997 became effective in February 1999.

Salient Features of New Exploration Licensing Policy (NELP)

The main features of NELP are:

- Private participation for intensive exploration of Indian basins.
- Provide scope and opportunity for opening up of acreages in ultra-deep water and frontier areas.
- To introduce new generation and state-of-the-art technology in exploration and exploitation.
- Equal distribution of playing field to all participating companies.
- Transparency in bid evaluation system.

Current System and Problems with NELP

It is at present the policy regime for exploration and production of oil and gas, as in existence for 18 years. The current system and various problems associated with it are as follows:

1. **Separate policies for different hydrocarbons:** At present, there are separate policies and licences for different hydrocarbons, such as conventional oil and gas, coal-bed methane, shale oil and gas and gas hydrates. In practice, the present framework leads to inefficiencies in exploiting natural resources.
2. **Profit sharing revenue model and delays:** The present regime is based on the principle of 'profit sharing' and Production Sharing Contracts (PSCs) are awarded under NELP. According to this, if a contractor discovers oil or gas, he is expected to share the profit as per the percentage given in his bid with the government. On the other hand, only royalties and cesses are paid to the government if no profit is made.
3. **Exploration confined only to some areas:** Exploration currently is confined to blocks, which the Government has put on tender.
4. **Unfair pricing:** The producer price of gas is currently fixed by the government. This has led to loss of revenue, considerable litigation, disputes and arbitrations.
5. **Unfair royalty charges under some cases:** While fixing royalties, the current system does not provide efficient distinction between shallow water fields with lower costs and risks and deep/ ultra-deep water fields with higher risks and costs.

3.18.2 HELP (Hydrocarbon Exploration and Licensing Policy)

Hydrocarbon Exploration and Licensing Policy is a policy adopted by Government of India in March 2016 indicating new contractual and fiscal modal for award of hydrocarbon acreage towards exploration and production.

HELP replaces present policy regime for E and P of oil and gas, known as **New Exploration licensing policy (NELP),** which has been in existence for 18 years. HELP aims to provide for a uniform licencing system and to

provide single licencing covering all hydrocarbons like oil, gas, coal-bed methane, etc.

Features

HELP has four main aspects:

- Uniform licence: Uniform licence for exploration and production of all forms of hydrocarbon.
- Open Acreages: Gives option to a hydrocarbon company to select exploration blocks throughout the year without waiting for government bid.
- Revenue Sharing Model: There will be no concern for the government regarding the cost incurred and will gain a share of gross revenue from sale of oil, gas, etc.
- Marketing and pricing freedom for crude oil and natural gas produce has been granted, subject to ceiling price limit, for new gas production from deep water. Provides pricing and marketing freedom to gas production from existing discoveries. Ceiling is calculated once in six months.

Significance of HELP

It paves way for the modernisation of the oil and gas exploration policy. It is expected to boost new exploration activities for oil, gas and other hydrocarbons and reduce import dependence. It can enhance the employment opportunities, especially in the petroleum sector. It has potential to bring in substantial investment into this sector. Disputes, corruption, administrative delays, administrative discretion, arbitrations and litigation will reduce and result in growth.

3.19 SMART GRID

It is an electrical grid using information and communication technology to collect data and act on information regarding the behaviour of suppliers and consumers in an automated fashion. Hence, Smart Grid is a generic label for the application of computer, intelligence and networking abilities to the existing electricity distribution system.

The grid offers smarter digital technology, allowing two-way communication between the utility and its customers and the sensing along the transmission line. The Smart Grid will consist of controls, computers, automation and new technologies and equipment working together, just like they are in the Internet. However, the difference is that, these technologies will work with the electrical grid to generate digital responses to our rapidly changing electric demand.

The smart grid will deploy technologies like state estimation that can improve detection of fault and allow self-healing of the network without requiring the technicians to intervene. The reliable supply of electricity and reduced vulnerability to natural disasters or attacks, assured by these grids, will be quite advantageous.

Reasons for Smart Grid

- Reduce carbon foot-prints.
- Self-healing.
- Improve distribution management and decision support software.
- Automated control for distribution.
- Increased efficiency.
- Sensing and measurement technologies.

The smart grid allows for systematic communication between suppliers (their energy price) and consumers (their willingness to pay). It permits both the suppliers and the consumers to be more flexible and sophisticated in their operational strategies.

Advantages

- Transmission of electricity will become more efficient.
- Electricity can be restored quickly after power disturbances.
- Reduction in operations and management costs for utilities, which ultimately lowers power costs for consumers.
- Reduced peak demand consequently lowering electricity rates.
- Integration of large-scale renewable energy systems can be increased.
- Better integration of customer-owner power generation systems, which includes renewable energy systems along with improved security.

3.20 NET METERING

Net Metering (or net energy metering – NEM) allows consumers who generate some or all of their own electricity to use that electricity any time, instead of when it is generated.

This is particularly important with wind and solar, which is non-dispatchable. Monthly net metering allows consumers to use solar power generated during the day and night or wind from a windy day later in the month.

Net metering is an enabling policy designed to faster private investment in renewable energy.

History of Net Metering: Net Metering originated in the United States, where small wind turbines and solar panels were connected to the electrical grid and consumers wanted to be able to use the electricity generated at a different time or date from when it was generated. Minnesota is commonly cited as passing the first Net Metering law in 1983.

Impact of Net Metering in India: Many Indian states have started implementation of Net Metering. States like Tamil Nadu, Karnataka and Andhra Pradesh have started implementation of Net Metering and the respective state electricity boards have announced the policy in 2014.

Controversy of Net Metering: Net Metering is controversial, as it affects different interest on the grid.

Advantages of Net Metering

- Giving customers control over their electricity bill.
- Creating job and encouraging private investment.
- Protecting the electric grid.

3.21 BUREAU OF ENERGY EFFICIENCY STAR LABEL

The Government of India has set up Bureau of Energy Efficiency (BEE) on 1st March 2002 under the provision of the Energy Conservation Act, 2001. The mission of BEE is to assist in developing policies and strategies with a thrust on self-regulation and market principles with the primary objective of reducing energy intensity of the Indian economy within the overall framework of the Energy Conservation Act, 2001. This will be achieved with active participation of all stakeholders, resulting into accelerated and sustained adoption of energy efficiency in all sectors.

Bureau of Energy Efficiency Star Label is the Standards and Labelling Programme to provide the consumer satisfaction at different levels about the energy and cost saving potential of various types of equipment (marketed, household and other equipments).

It is currently invoked for various equipments/ appliances like Computer, Direct Cool Refrigerator, Stationary Type Water Heater, Submersible Pump Set, Frost Free Refrigerator, Room Air Conditioner, Ceiling Fan, Opens well Submersible Pump Set, Diesel Engine, Driven Mono set pumps. For Agricultural Purposes, Diesel Generator Set Distribution Transformer, Domestic Gas Stove, Monoset Pump, Solid State Inverter, Office Automation Products, Led Lamps, Inverter AC, Colour Television and General Purpose Industrial Motor.

3.22 'ONE NATION, ONE GRID'

It will be high-voltage electric power transmission network in mainland India, connecting power stations and major substations and ensuring that electricity generated anywhere in mainland India can be used to satisfy demand elsewhere.

Evolution of National Grid

1. Grid management on regional basis started in 1961.
2. Initially, State grids were inter-connected to form regional grid and India was demarcated into five regions namely Northern, Eastern, Western, North Eastern and Southern region. In August 2006, North and East grids were interconnected thereby four regional grids Northern, Eastern, Western and North Eastern grids are synchronously connected forming central grid operating at one frequency.
3. On 31st December 2013, Southern Region was connected to Central Grid in Synchronous mode with the commissioning of 765 kV Raichur–Solapur Transmission line thereby achieving **'ONE NATION'-'ONE GRID'-'ONE FREQUENCY'.**

Benefits of a National Grid

1. Better availability resulting in lesser power cuts.
2. More stability in power.
3. Better synchronisation.

3.23 ENERGY MODELLING

- Energy modelling or energy system modelling is the process of building computer models of energy systems in order to analyse them.
- Such models often employ scenario analysis to investigate different assumptions about the technical and economic conditions at play.
- Outputs may include the system feasibility, greenhouse gas emissions, cumulative financial costs, natural resource use and energy efficiency of the system under investigation.

Energy Modelling Forums (EMF)

- The Energy Modelling Forum (EMF) in United States was established in 1976 at Stanford University to connect leading modelling experts and decision makers from government, industry, universities and other research organisations.
- The forum provides an unbiased platform to discuss the contemporary issues revolving around energy and environment.

India Energy Modelling Forum

- It was jointly launched by **NITI Aayog** and **United States Agency for International Development (USAID)** under the US–India Strategic Energy Partnership.
- **Composition:** The forum would include knowledge partners, data agencies and concerned government ministries.
- **An inter-ministerial:** The committee will be convened by NITI Aayog and headed by its CEO, and comprise senior officials from the ministries of petroleum and natural gas; power; new and renewable energy; coal; environment, forest and climate change; and department of science and technology. This committee will review the studies/modelling activities and provide directions and new areas of research.
- **A steering committee:** This committee will shortlist policy issues to be taken up for study and might form various taskforces depending on the specific studies/modelling exercises to be carried out.

Aims of the Forum

1. Provide a platform to examine important energy and environmental-related issues;
2. Inform decision-making process to the Indian government;
3. Improve cooperation between modelling teams, government and knowledge partners, founders;
4. Facilitate exchange of ideas, ensure production of high-quality studies;
5. Identify knowledge gaps at different levels and across different areas;
6. Build capacity of Indian institutions.

3.24 ENERGY CHALLENGES IN INDIA

Approximately a quarter of the India's population does not have any access to electricity. It has been recognised that energy poverty is the reason behind the slow economic development. Thus, access to energy for its entire population has been among top priorities of Indian policy makers. Energy security has a prime spot in government policy making. Earlier, weightage was given to electricity shortage and disappointed energy needs. Still, the high dependency rate on imported energy sources, such as oil, natural gas and coal, brought the subject into light. In India, energy security can be broadly described as supplying lifeline energy to all of our people, regardless of their capacity in paying as well as meeting its effectual demands for secure and suitable energy and satisfying its different requirement at reasonable prices all times with a set level of confidence with fair consideration to reasonably expected shocks and disruptions.

Even though the government took up the policy to diversify fuel, the main importance was given to the maximum utilisation of what is available in India (Thorium, Hydrocarbons, etc.). Dr. A.P.J. Abdul Kalam, the then president, announced a plan to realise zero dependence and move to renewable energy sources.

Challenges in India

1. India's primary challenge is to maintain a steady economic growth. A well-developed energy sector is prime for its high functioning and financially sound economy. This will want an enhanced move towards an energy sector on the basis of market economy. The two prime challenges in the country's energy sector are:
   - **Shortage of electricity** as a result of energy shortages across different fuel sectors which, in turn, hampers economic and social development.
   - The **low domestic production** pushes it to a position of deficit and hence requiring import of energy resources.
   - **Enhancing Energy Security:** The main reason behind the dependency on the imports of energy sources is the high demand of the developing economy, which results in crises due to low domestic production. This dependency questions our policies of a future

energy security, which is the most important challenge to the Indian Ministry of Power.

2. **Ensuring Energy Distributions and Supply:** In the country's power sector, the coal and natural gas shortages are important issues for power generation. The key causes for unsatisfactory supply of coal:
   - Flat domestic coal production due to delayed cases of mining. Slow acquisition of land as well as stern clearance in environment.
   - Controlled coal import because of inadequate import infrastructures and also due to the high difference in price.
3. **Challenges of Energy Project Infrastructure:** Inadequate equipment and services in the power sector along with facilities that contain these equipments are a major disappointment.
4. **Rural Electrification:** Electrification of rural India is the key to achieve high economic growth as well as employment, which would ultimately result in low poverty. There are huge number of rural areas that are still not privileged to have electricity.
5. **Development of Renewable Energy Sources:** Following challenges are major obstacles in our way to energy security:
   - Solar lanterns can be used for lighting in place of kerosene as a fuel, being a cleaner and brighter substitute.
   - Biomass technology, though is abundantly present in the country, India has unfortunately failed to manage in achieving the installations scale with regard to its potential.
   - India's rank is fifth in the world in terms of hydropower potential. However, the potential developed so far is even less than 25%.
   - Geothermal technology can power geothermal plants for application of projects of small-scale intensity. However, its application is faintly used so far.
6. **Making Use of Nuclear Power:** Despite consistent efforts, commitments and advances, India's nuclear power capacity remains small. The current generation capacity of nuclear power is 4.8 gigawatts and with this, India ranks thirteenth in the world, accounting to world's 12% nuclear capacity. All this is linked to the country's long separation from the nuclear global energy regime and its focus on the nuclear programmes, which are thorium-based. India's energy challenges can greatly be addressed by adequate and efficient application of nuclear energy.

   The present challenges in the development and the utilisation of renewable sources of energy and nuclear energy have to be well tapped, so as to enhance India's chances of being energy sufficient and greatly solve the serious energy shortage. This, in turn, would also limit the country's growing import pressure and produce feasible business opportunities.
7. **Striving towards Sustainable Development:** One of India's top priorities is boosting the energy sector. There is close connection between energy security and economic growth and poverty alleviation. The biggest challenge is seen to acquire adequate economic growth with no harm to the environment, and supporting conversation of environment.

   Balanced energy mix, which means adequate balance between application of all non-renewable energy sources and an increasing renewable energy share, will enable the country to achieve multiple objectives like sustainable development challenges, meeting food, water and fuel basic needs for an increasing population, etc.

3.25 ENERGY POLICY OF INDIA

India uses both conventional resources such as coal, lignite, petroleum and natural gas, as well as non-conventional energy sources such as hydro, wind, solar biomass and the cogeneration biogas.

It aims that the energy needs of the country are achieved at the lowest possible cost in real resources, with attaining sufficient security and stability in reliability and supply with environment, social and other objectives of policy.

3.26 INTEGRATED ENERGY POLICY

In order to address the ever-increasing demand and millions of people's aspirations, along with the accessibility of energy security and other vital resources, there is a need to formulate the country's integrated energy policy, with a vision for ensuring an unconstrained supply of energy and further replenishing

the whole energy sources. This will ultimately ensure the country's sustainable development.

Vision of Integrated Energy Policy: This policy, as depicted by India's Planning Commission/NITI Aayog, aims primarily **to make India self-reliant in terms of energy security, which can achieve the demands of all sectors and energy services, including the lifeline energy requirement of weak household.**

Through this policy, **it is aimed to supply all parts of the country with clean, safe and convenient energy at the minimum cost. The policies should be efficient, technically, viable, economically and environmentally sustainable. The ultimate energy policy goal is to supply energy security to all.**

Sustainable Development

Sustainable development is directly related to environment protection and precisely, it is described as, the development meeting the needs of the present with no compromise on the ability of future generations to meet their own needs.

Challenges

Energy security and environmental protection, at the same time, pose the biggest challenge in India's path towards sustainable development.

Role of Integrated Energy Policy in India

The policy appears to be an effective promise towards fulfiling India's aspirations of becoming energy secured nation and status of responsiveness towards the environment.

3.27 INTERNATIONAL ENERGY AGENCY (IEA)

The **International Energy Agency (IEA)** has invited **India, the world's third-largest energy consumer,** to become its full-time member.

Implications

The proposal if accepted will require New Delhi **to raise strategic oil reserves to 90 days requirement.** India's current strategic oil reserves equal 9.5 days of its requirement.

Background

In March 2017, India became an associate member of IEA.

About IEA

- Established in 1974 as per the framework of the OECD, IEA is an autonomous intergovernmental organisation.
- Its mission is guided by four main areas of focus: energy security, economic development, environmental awareness and engagement worldwide.
- Headquarters (Secretariat): Paris, France.

Roles and Functions

- Established in the wake of the 1973–1974 oil crisis, to help its members respond to major oil supply disruptions, a role it continues to fulfil today.
- IEA's mandate has expanded over time to include tracking and analysing global key energy trends, promoting sound energy policy, and fostering multinational energy technology cooperation.

Composition and Eligibility

- It has 31 members at present. IEA family also includes eight association countries. A candidate country must be a member country of the OECD. But all OECD members are not IEA members.
- To become member a candidate country must demonstrate that it has:
  1. Crude oil and/or product reserves equivalent to 90 days of the previous year's net imports, to which the government has immediate access (even if it does not own them directly) and could be used to address disruptions to global oil supply.
  2. A demand restraint programme to reduce national oil consumption by up to 10%.
  3. Legislation and organisation to operate **the Co-ordinated Emergency Response Measures (CERM)** on a national basis.
  4. Legislation and measures to ensure that all oil companies under its jurisdiction report information upon request.
  5. Measures in place to ensure the capability of contributing its share of an IEA collective action.

Reports

- Global Energy & CO_2 Status Report.
- World Energy Outlook.
- World Energy Statistics.
- World Energy Balances.
- Energy Technology Perspectives.

3.28 PSUs AND OTHER ORGANISATIONS

S.No.	PSU and other Organisation	Main Features
1.	National Thermal Power Corporation Limited (NTPC Ltd.) (1975)	A Maharatna Company of the Government of India, it is the single largest power generator in India, with a vision of being world's largest and best power producer, capable of powering India's growth and a mission to develop and provide reliable power and related products and services at competitive prices. Besides this, integration of multiple energy sources with innovative and eco-friendly technologies, which can efficiently contribute to society is another crucial part of its vision. The Government of India holds 75% of its authorised share capital. NTPC has attained the position of global Number 1 Independent Power Producer in the world, among the top 250 Global Energy Companies for 2013.
2.	National Hydroelectric Power Corporation Ltd (NHPC) (1975)	A Mini Ratna Enterprise of the Government of India has emerged as the largest organisation for hydro-power development in India. The company is listed with the BSE and NSE. The main objective of NHPC includes planning, promoting and organising an integrated and efficient power development in all of its aspects through conventional and non-conventional sources in India and abroad. Besides this, it also takes care of the transmission, distribution, trading and sale of power generated at stations.
3.	Power Grid Corporation of India (PGCIL) (1989)	POWERGRID was incorporated as a Government enterprise for establishment of operation of regional and national power grids that can facilitate transfer of power within and across the regions with reliability, security and cost effectiveness as well (based on sound commercial principles). Government of India also conferred the Maharatna on POWERGRID in 2019.
4.	Rural Electrification Corporation Limited (REC) (1969)	REC was incorporated as a company under Companies Act, 1956 in 1969. Its main objective is financing rural electrification schemes in the country. Under the Companies Act, 2013, it has the status of a public financial institution, and under RBI Act, 1934, REC is also registered as a Non-Banking Financial Company. REC is a 'Maharatna Company'. REC is financing large/mega generation projects, transmission and distribution projects and also the nodal agency for implementation of RGGVY.
5.	Power Finance Corporation Limited (PFC) (1986)	PFC is a leading financial institution of this sector and a NBFC, which assists with financial and non-financial support for developing this sector. PFC is a Maharatna CPSE in the Financial Services Sector, under the administrative control of the Ministry of Power with 73.72% of the shareholding of GDI. PFC provides technical, management advisory and consultancy services, related activities through its subsidiary-company, namely PFC Consulting Limited. RBI reclassified PFC from a Loan Company to an Infrastructure Finance Company in July 2010.
6.	North Eastern Electric	North Eastern Electric Power Corporation Limited is a Miniratna Company currently meets more than 60% of the energy requirement of the North-East region. It is an ISO 9001:2000 (Quality), ISO 14001:1996 (Environment) and OHSAS18001:1999 (Safety) Company.
7.	Satluj Jal Vidyut Nigam	A joint venture of the Government of India and the Government of Himachal Pradesh. The equity participation in it is in the ratio of 75:25 between GOI and Government of Himachal Pradesh. It functions to plan, investigate, organise, operate and maintain hydro-electric power project. SJVN is a Mini Ratna company.
8.	THDC India Limited	To plan, promote and organise an integrated hydro resources of Bhagirathi river and its tributaries at Tehri like Tehri Hydro Power Complex and other hydro projects. THDC India Limited (formerly Tehri Hydro Development Corporation Limited), is under the ownership of National Thermal Power Corporation Limited, Ministry of Power, Government of India and is a Miniratna Company.
9.	Damodar Valley Corporation (DVC)	DVC's main projects include four dams at Maithon, Panchet, Tilaiya and Konar, Thermal Power Stations at Bokaro 'A', Bokaro 'B', Chandrapur, Durgapur, Mejia and also one gas turbine station at Maithon. The first multipurpose river valley project with the objectives of flood control, irrigation and hydel power generation in the Damodar Valley region (Jharkhand and West Bengal).
10.	Bhakra Beas Management	The board is responsible for administering, maintaining and operating at Bhakra Nangal Projects, and regulating water supply for irrigation from Bhakra Nangal and Beas projects to the states of Punjab, Haryana and Rajasthan and also drinking water supply to Delhi and Chandigarh.
11.	Power Trading Corporation of India Ltd. (PTC)	It is a single entity to enter into power purchase agreement. It is also a nodal agency (PTC) to deal with matters related to exchange of power between India and neighbouring countries.

S.No.	PSU and other Organisation	Main Features
12.	National Power Training Institute (NTPI)	A registered society under Ministry of Power, Government of India is committed to develop Human Resources in Power Sector. Eight institutes are being operated by NTPI, with its corporate centre at Faridabad, all over the country. There are five regional institutes, which are located at Neyveli (Tamil Nadu), Durgapur (West Bengal), Badarpur (New Delhi), Nagpur (Maharashtra) and Guwahati.
13.	Central Power Research Institute (CPRI)	It carries out applied research in electrical power engineering. Serving as the National Testing and Certification Authority for electrical equipments, it has been given the 'Observer Status' in the group of Short Circuit Testing Liasion' (STL) of Europe.

4.1 DEPARTMENT OF ATOMIC ENERGY

The **Department of Atomic Energy (DAE) was set up on 3 August 1954** with the vision of empowering India through making it energy independent, contributing to provision of sufficient, safe and nutritious food and better healthcare to our people through development and deployment of nuclear and radiation technologies and their applications. **The DAE works directly under the Prime Minister of India**. The nuclear technology, including nuclear power and research, is taken care of by this department.

It is engaged to design, construct and operate nuclear power/research reactors and support nuclear fuel cycle technologies. On the whole, it will cover exploration, mining and processing of nuclear minerals, production of heavy water, nuclear fuel fabrication, fuel reprocessing and nuclear waste management. The department is also developing new elite crop varieties including oil seeds and pulses along with techniques for biological control of pests and pathogens, which ultimately protects the crops, radiation-based post-harvest technologies, radiation-based techniques for diagnosis and treatment of diseases, particularly cancer, technologies for safe drinking water, better environment and robust industry etc.

ATOMIC ENERGY COMMISSION

The Indian Atomic Energy Commission was **first set up in August 1948 in the Department of Scientific Research. Important functions of the Atomic Energy Commission** are:

- To organise research for atomic scientists in the country.
- To train atomic scientists in the country.
- To promote nuclear research in the Commission's own laboratories as well as in India.
- To undertake prospecting of atomic minerals in India and to extract such minerals for use on an industrial scale.

The following are significant contributions made by the DAE to national initiatives:

- **Agriculture:** To enhance the production of oilseeds and pulses.
- **Education and Health:** Various institutions work for this promotion – Homi Bhabha National Institute (HBNI), Countrywide-Services in Cancer through Telemedicine, National Initiative on Undergraduate Science (NIUS).
- **Food and Nutrition Security:** Radiation-based processing of food and agro products enhances and saves these products.
- **Water Resources:** It also helps in the desalination of water in water-scarce areas along the sea coast.
- **Energy Security:** Electricity generation and its supply that will make India self-dependent.

4.2 RESEARCH AND DEVELOPMENT SECTOR IN ENERGY GENERATION

Various centres and research institutions are established that work for energy generation in India.

1. Bhabha Atomic Research Centre
2. Variable Energy Cyclotron Centre
3. Global Centre for Nuclear Energy Partnership
4. Indira Gandhi Centre for Atomic Research
5. Raja Ramanna Centre for Advanced Research
6. Atomic Minerals Directorate for Exploration and Research

4.2.1 Bhabha Atomic Research Centre

It is the premier multi-disciplinary research centre of India which has excellent infrastructure that **facilitates advanced research and development covering the entire spectrum of nuclear science** as well as areas related to engineering.

4.2.2 Variable Energy Cyclotron Centre

It is a premier centre for frontier research and development in the fields of accelerator science and technology, computer science and technology, nuclear science (theoretical and experimental), material science and other such relevant areas.

4.2.3 Global Centre for Nuclear Energy Partnership

The Global Centre for Nuclear Energy Partnership (GCNEP) is under construction at Kheri Jasaur, near Bahadurgarh, Haryana, India. The centre will consist of five schools for advanced research, study and training of nuclear systems and facilities.

4.2.4 Indira Gandhi Centre for Atomic Research

In 1971, the Indira Gandhi Centre for Atomic Research (IGCAR) was established under the DAE. Since its inception, it has been engaged as multidisciplinary programmes of scientific research and advanced engineering, aiming towards the development of a fast breeder reactor (FBR) technology. Uniquely mixed plutonium–uranium carbide fuel (first of its kind in the world) and KAMINI Reactor (the only operating reactor in the world using U-233 fuel) are two important specialities of this reactor.

4.2.5 Raja Ramanna Centre for Advanced Research

The DAE established the Raja Ramanna Centre for Advanced Technology (RRCAT) in Indore, Madhya Pradesh, India. This enables India to expand the activities carried out at the Bhabha Atomic Research Centre (BARC), Mumbai, in two major areas of science and technology, namely Lasers and Accelerators. The first batch of scientists from the BARC, Mumbai, moved to the RRCAT in June 1986, and this initiated the scientific activities.

4.2.6 Atomic Minerals Directorate for Exploration and Research

Identification and evaluation of uranium resources required to successfully implement an atomic energy programme in the country is the mandatory factor for the Atomic Minerals Directorate for Exploration and Research.

4.3 NUCLEAR ENERGY

Nuclear energy utilises nuclear fuel to generate heat, which is used in steam turbines to produce electricity in a nuclear power plant. There are two modes of use of nuclear energy, i.e. nuclear fission and nuclear fusion (Table 4.1). Nuclear reactions such as nuclear fission (when a single heavy nucleus splits into two smaller nuclei) and nuclear fusion (when a single heavy nucleus is formed from the combination of two lighter atomic nuclei) release very high amounts of energy. In

TABLE 4.1 Difference between Nuclear Fission and Nuclear Fusion

Characters	Nuclear Fission	Nuclear Fusion
Definition	The splitting of a large atom into two or more smaller ones is known as nuclear fission.	The fusing of two or more lighter atoms to form a larger or heavier one is termed as nuclear fusion.
Natural occurrence of the process	It does not occur normally in nature and needs to be induced.	It occurs naturally and is the source of energy of stars, such as the sun.
By-products of the reaction	Many highly radioactive particles are produced.	Few radioactive particles are produced; however, through fission 'trigger', radioactive particles will result from that.
Conditions	Critical mass of the substance and high-speed neutrons are basic requirements.	High-density and high-temperature environment are basic requirements.
Energy requirement	Splitting requires little energy in a fission reaction.	Extremely high energy is required to bring two or more protons close enough, resulting in overcoming of electrostatic repulsion by the nuclear forces of the participating atoms.
Energy released	The energy so released is million times greater than that released in chemical reactions, but lower than that by nuclear fusion.	Three to four times greater energy is released.
Nuclear weapon	A nuclear weapon or fission bomb, also known as an atomic bomb or an atom bomb is produced through application of nuclear fission.	A nuclear weapon is the hydrogen bomb, using a fission reaction to 'trigger' a fusion reaction.
Energy production	Nuclear power plants are practical applications of nuclear fission reactions.	An experimental technology for producing power.
Fuel	Uranium is the primary fuel used in power plants.	Hydrogen isotopes (deuterium and tritium) are the primary fuels used in experimental fusion power plants.

a nuclear fission reaction, radioactive decay happens in spontaneous breakdown of a radioactive atomic nucleus and results in the release of energy. Atom bomb and nuclear energy development programme of India are based on nuclear fission. Solar energy, hydrogen bomb and artificial sun research (ITER – International Thermonuclear Experimental Reactor) are examples of nuclear fusion. In the sun, the process of hydrogen fusion converts about 4 million tonnes of solar matter per second into electromagnetic energy, which is radiated into space. In 1896, nuclear energy or atomic energy, which is used as a power source, was first discovered by the French scientist Henri Becquerel.

Note: Very large and heavy atoms occurring in nature are unstable and hence show radioactivity. Examples include: atoms of the element uranium (atomic number or Z = 92), thorium (atomic number = 90), radon (atomic number = 86) and radium (atomic number = 88), among others. Many smaller atoms are artificially turned radioactive for specific uses. They include carbon (atomic number = 6), which often has a stable form but can be turned into non-radioactive form as well as unstable radioactive form.

4.3.1 Nuclear Power in India

APSARA was the first nuclear research reactor in India. Its design was conceptualised by Dr Homi Bhabha (the Father of the Indian Nuclear Programme) in 1955. The reactor was built with assistance from the United Kingdom who provided the initial fuel. On 4 August 1956, the reactor reached criticality and was inaugurated on 20 January 1957. Further, another research nuclear reactor and its **first nuclear power plant were built with assistance from Canada**. In 1956, a 40-megawatt research reactor agreement was signed, and the Canadian-Indian Reactor, US (CIRUS) achieved first criticality in 1960. India got this reactor supplied on the assurance of applying for the military purposes, but without effective safeguards against such use. For India's first nuclear power plant at Rajasthan, RAPP-1 (Rajasthan Atomic Power Project), an agreement was signed in 1963, followed by RAPP-2 in 1966. To ensure no application of these reactors for a military programme, these reactors contain rigid safeguards unlike before. **The 200-megawatt RAPP-1 reactor was based on the CANDU (Canada Deuterium Uranium) reactor and its operation started in 1972.** However, owing to technical problems, the reactor was down rated from 200 megawatts to 100 megawatts. AECL (Atomic Energy of Canada Limited) provided free technical and design information to India. **After India's first nuclear explosion in 1974, the assistance from the United States and Canada was terminated.** The fourth largest source of electricity in India after thermal, hydroelectricity and renewable sources of electricity is nuclear power.

Note:

1. **Use of Nuclear Energy for Power Generation (PIB Report)*:** Presently, nuclear power is saving 41 million tonnes of CO_2 emissions annually, compared to the emissions that would be generated by equivalent electricity generation from coal-based thermal power plants. Currently, nuclear power provides 3% of electricity generation. Sufficient production and share of nuclear power is essential for ensuring the country's energy security. Current policy targets a three-fold rise in nuclear installed capacity by 2032.

   It was pointed out that the present installed nuclear power capacity is set to increase from 6780 MW to 22480 MW by 2031 on progressive completion of projects under construction and accorded sanction. In the next 3 years, capacity addition of 5300 MW is planned on completion of KAPP 3&4 (2 × 700 MW), RAPP 7&8 (2 × 700 MW), KKNPP 3&4 (2 × 1000 MW) and PFBR (500 MW). (**KAPP** – Kakrapar Atomic Power Plant, **RAPP** – Rajasthan Atomic Power Plant, **KKNPP** – Kudankulam Nuclear Power Plant and **PFBR** – Prototype Fast Breeder Reactor)

   * https://pib.gov.in/PressReleasePage.aspx?PRID=1809285 (last accessed in June 2023).
2. **Nuclear Vision of India:** India has a flourishing and largely indigenous nuclear power programme and expects to have 63,000 megawatts electric (MWe) nuclear capacities on line by 2032. It aims to supply 25% of electricity from nuclear power by 2050.

4.3.2 Types of Nuclear Reactions

Basically there are two types of reactions, which take place to release nuclear energy (see **Table 4.1**):

1. Nuclear fission
2. Nuclear fusion

4.3.2.1 Nuclear Fission

Nuclear fission is the process of splitting of a large nucleus into two smaller nuclei with the release of energy. In other words, fission is the process in which a nucleus is divided into two or more fragments and neutrons and energy are released. When any uranium nucleus ($_{92}U^{235}$) is bombarded with a neutron, the nucleus splits up into almost equal fragments with the release of some free neutrons and tremendous amount of energy per $_{92}U^{235}$ nuclei. Such a nuclear reaction is called nuclear fission. For example: **Atom bomb, Nuclear Energy Development Programme of India.** The schematic equation for fission process may be written as:

$$_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{144} + {}_{36}Kr^{89} + {}_{30}n^{1} + \text{Energy (200 MeV)}$$

4.3.2.2 Nuclear Fusion

When two or more light nuclei, moving with very high speeds, are fused together to form a single nucleus, then this process is called nuclear fusion. The mass of the product nucleus is less than the sum of masses of the nuclei, which are fused. The lost mass is converted into energy, which is released in the form of fusion energy. The number of deuterons (reactants of the fission reaction) in 1 gram of heavy hydrogen is much larger than the number of U^{235} nuclei in 1 gram of uranium. Thus, the energy output per unit mass of the material consumed is much more in the case of fusion of the light nuclei than in the case of the fission of heavy nuclei. For example: **Solar energy (sunlight), Hydrogen bomb, International Thermonuclear Experimental Reactor (Artificial Sun Experiment)**. Fusion reactions are observed in the equation as below: (Q = heat)

$$_{11}H^1 + {}_1H^1 \rightarrow {}_1H^2 + e + Q \qquad Q = 0.42 \text{ MeV}$$

$${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 \qquad Q = 3.3 \text{ MeV}$$

NUCLEAR ENERGY DATA WORLDWIDE

- The first commercial nuclear power stations started operation in the 1950s.
- Nuclear energy now provides about 10% of the world's electricity from about 440 power reactors.
- Over 50 countries utilise nuclear energy in about 220 research reactors. In addition to research, these reactors are used for the production of medical and industrial isotopes, as well as for training.
- India has 22 operable nuclear reactors, with a combined net capacity of 6.8 GWe. In 2021, nuclear generated 3.2% of the country's electricity. The Indian government is committed to growing its nuclear power capacity as part of its massive infrastructure development programme. The government in 2010 set an ambitious target to have 14.6 GWe nuclear capacity online by 2024. At the end of July 2022 eight reactors were under construction in India, with a combined capacity of 6.7 GWe.

4.3.3 India's Three-Stage Civil Nuclear Power Programme

In 1954, during the forum of the 'Development of Atomic Energy for Peaceful Purposes', Bhabha conferred the three-stage plan for the country's development and the same was also attended by the country's first Prime Minister, Jawaharlal Nehru. The three-stage plan was formally adopted by the Indian government after 4 years, that is, in 1958. Consequently, thorium was recognised by the Indian government, as a source capable for providing power to the country in the long term.

4.3.3.1 First Stage

Fuel – Natural uranium
Reactor – PHWR (pressurised heavy-water reactor)
Moderator – D_2O (heavy water)
Coolant – D_2O (heavy water)

Pressurised heavy-water reactors (PHWRs), which are fuelled with natural uranium, generate electricity during the first stage of the programme, which generates plutonium-239 as a by-product.

The fissile isotope content is only 0.7% in natural uranium-235. However, most of the remaining 99.3% is uranium-238, which is although not fissile, in a nuclear reactor, can be converted to the fissile isotope plutonium-239. Three per cent enrichment of uranium-235 is required for electricity generation but as an atom bomb, its enrichment should be more than 20% (to up to 90%).

4.3.3.2 Second Stage

Fuel – Plutonium
Reactor – FBR (fast breeder reactor)
Moderator – Not in use/Rarely used
Coolant – Liquid sodium (liquid Na)

A mixed oxide (MOX) fuel is used in the FBRs prepared from plutonium-239, which is recovered by reprocessing spent fuel at the first stage, and natural uranium. This is the major process occurring during second stage. In FBRs, plutonium-239 experiences fission, producing energy. On the other hand, the mixed oxide fuel carrying uranium-238 transforms to extra plutonium-239. Hence, the stage-two FBRs are intended to 'breed' additional fuel than their consumption. After the building of plutonium-239 inventory, thorium in a reactor is used as a blanket material and transformed to uranium-233. The U-233 so produced can be used in the third stage.

4.3.3.3 Third Stage

Fuel – Thorium
Reactor – Advanced heavy-water reactor (AHWR) and thermal breeder reactor (TBR)
Moderator – Light water (demineralised water)
Coolant – D_2O (heavy water)

An advanced or stage-three nuclear power system entails a self-sustaining series having fuelled reactor consisting of thorium-232 and uranium-233. According to this three-staged plan, the country's nuclear energy could grow to nearly 10 gigawatts with the help of PHWRs fuelled by domestic uranium. The nuclear energy growth over that could come only from FBRs till nearly 50 gigawatts. Only after achieving this capacity, the third stage is to be deployed.

India is currently focussing on the design of a reactor, which will enable more straightforward utilisation of thorium that is analogous with the three-stage sequential programme due to delay in direct utilisation of thorium. The accelerator-driven systems (ADS), advanced heavy-water reactor (AHWR) and compact high temperature reactor are the current three options that are being considered for the same. Even a molten salt reactor might be under deliberation, as per several current reports. (Refer **Infographic – India's 3-Stage Nuclear Development Programme**).

4.3.4 Nuclear Fuel

4.3.4.1 First-Stage Fuel – URANIUM

Martin Klaproth, a German chemist, discovered uranium in 1789 in the mineral called **pitchblende**. It derives its name from Planet Uranus, which was discovered 8 years earlier. The melting point of uranium is 1132°C. It occurs in low concentration in soil, rock and water. Commercially, it is extracted from uranium-bearing minerals such as uraninite and pitchblende.

In nature, uranium is found as **uranium-238 (99.2742%), uranium-235 (0.7204%)** and a very small amount of **uranium-234 (0.0054%)**. Under certain conditions, the U-235 isotope can readily split, with a high yield of energy and thus adds to its importance. Hence, it is described as 'fissile' and the expression 'nuclear fission' is used. U-238 decays very slowly but **U-235 decays slightly faster.**

4.3.4.1.1 Enriched Uranium

A type of uranium in which through the process of isotope separation, the per cent composition of uranium-235 has been increased is called enriched uranium. For both, civil nuclear power generation and military nuclear weapons, enriched uranium serves as a critical component. The monitoring and controlling of enriched uranium supplies and processes are attempted by the International Atomic Energy Agency (IAEA), in its efforts to ensure nuclear power generation safety and curb nuclear weapons proliferation.

From uranium ore to reactor fuel:

- **Low-enriched uranium** (Reactor Grade-Electricity): 3–5% $_{92}U^{235}$.
- **High-enriched uranium** (Weapon Grade): 90–95% $_{92}U^{235}$.

4.3.4.1.2 Uranium in India

The Uranium Corporation of India, a DAE subsidiary, is responsible for mining and processing of uranium at **Jaduguda** and **Bhatin** (since 1967), **Narwapahar** (since 1995) and **Turamdih** (since 2002) – all in Jharkhand.

4.3.4.2 Second-Stage Fuel – PLUTONIUM

The U-235 nucleus is 'fissile', while the nucleus of U-238 is said to be 'fertile'. It implies that it can capture one of the neutrons, which are flying about in the core of the reactor and become (indirectly) plutonium-239 that is the fissile form. Both Pu-239 and U-235 are similar, in terms of the fission process on hitting by a neutron, yielding enormous energy. Sometimes, on capturing a neutron, splitting of Pu-239 atom does not happen and instead it becomes Pu-240. Due to the more unstable nature of Pu 239, it is used for atom bombs. Pu-240 has less stability so it is used in nuclear reactors for electricity generation.

Note: After addition of a single neutron, Pu 239 will become Pu 240.

4.3.4.3 Third-Stage Fuel – THORIUM

Thorium was discovered in 1828 and named after Thor, the Norse god of thunder. It is a natural radioactive chemical element with the symbol Tn^{232} and atomic number 90. In nature, virtually all thorium is found as thorium-232, and through emission of an alpha particle, is decayed. Its half-life is of about 14.05 billion years

(other, trace-level isotopes of thorium are short-lived intermediates of decay chains). **Thorium is estimated to be about four times more abundant than uranium** in the earth's crust and is a by-product, while extracting rare earth metals from monazite sands.

4.3.4.3.1 How Thorium is Better than Uranium?

Starting from the mining and purification, thorium is advantageous. However, a trace of naturally occurring thorium is Th^{232}, the isotope useful in nuclear reactors. It is much better than 3–5% of uranium that comes in the form we require. Unlike U^{235}, thorium is not fissile, that is, they will not start splitting on their own and exploding, no matter how many thorium atoms are packed together. So, to stop the reaction, the source of neutrons needs to be turned off, shutting the whole process down.

Here's how thorium works:

On absorbing a neutron, Th^{232} becomes Th^{233}, i.e., the unstable form which decays into protactinium-233 and then into U^{233}.

4.3.4.3.2 Potential Benefits of Using Thorium

If thorium reactors are as safe as claimed by the proponents, there may be no need to construct them as fortresses (which are expensive) because traditional reactors may cause disasters and involve radiations, which are harmful. Some thorium, obtained as a by-product of rare earth material mining of monazite, has a sustainability advantage, as it requires no additional mining to extract it, thus reducing further environmental destruction and financial cost.

PRESENCE OF THORIUM

Worldwide

First rank – India (21%), Second rank – Australia (19%), Third rank – United States (13%) and Fourth rank – Turkey (11%).

In India

It dominates the eastern coastal region in India. First rank – Andhra Pradesh (31%), Second rank – Tamil Nadu (21%), Third rank – Odisha (20%), Fourth rank – Kerala (16%), Fifth rank – West Bengal (10%), Sixth rank – Jharkhand (2%).

4.3.4.3.3 Thorium in India

India is capable of using thorium cycle-based processes for extraction of nuclear fuel, which is significant for the Indian nuclear power generation strategy because India has large reserves of thorium – about 660,000 tonnes in Kerala. Such large reserves can fuel nuclear projects for an estimated 2,500 years. Though the FBRs need higher cost for construction as compared to the PHWRs. India is focussing at the cheaper option – uranium fuel.

Note: India's first thorium-based commercial breeder reactor – 500 MW Prototype Fast Breeder Reactor (PFBR) – is working at the Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu. A total of 30% energy generation in India is targeted with the help of thorium reserves by 2050 in all nuclear energy generation targets.

MONAZITE

Monazite is a primarily reddish-brown phosphate mineral that **contains rare-earth elements**. Monazite is considered as a group of minerals due to its variability in composition. It is an atomic mineral that occurs naturally in the coastal sands of three districts: **Tirunelveli, Thoothukudi and Kanyakumari** in India.

Monazite is an important ore for thorium, lanthanum and cerium. Today, most of the world's monazite is produced in the offshore waters of India, Madagascar and South Africa.

4.3.4.3.4 Difference between Thorium and Uranium

Thorium is more abundantly present in nature than uranium. Thorium is not fissile; and hence cannot go critical and generates a nuclear chain reaction. Thorium produces less radioactive waste products and generates more energy per tonne, so it is safe for the environment too. Thorium reactors do not produce plutonium, which is what you need to make a nuclear warhead. Thorium-derived U^{233} is a better fuel on the basis of efficiency of energy generation in nuclear reactor, in comparison to U^{235}.

4.3.4.3.5 Other Uses of Thorium

- Thorium is found in the filaments of vacuum tubes, e.g. magnetron found in a microwave oven.
- Oxides of thorium known as 'thoria' are used in industry. Melting point of thoria is very high, so it is used in mantles of portable gas lights.

- When 'thoria' is added to glass, it increases the refractive index and decreases dispersion and is hence used in high-quality lens for cameras.
- As a chemical catalyst for converting ammonia to nitric acid in petroleum cracking and in production of sulphuric acid.

DISTINCTION BETWEEN FISSILE AND FISSIONABLE

Fissile materials can fission by absorbing a neutron with very low kinetic energy. The addition of neutron adds enough energy for the fissile material to undergo fission, owing to the odd number of neutrons in the nucleus, which will 'rearrange' themselves for releasing energy. U-235, Pu-239 and Pu-241 are fissile.

Fissionable materials can fission through absorption of a neutron if it has enough kinetic energy. The neutron needs to bring enough kinetic energy to the nucleus so that it can undergo fission. U-238 and Pu-240 are fissionable.

All fissile nuclides are fissionable, but only some fissionable nuclides are also fissile.

4.3.5 Nuclear Reactor

A nuclear reactor, or an atomic pile, is a device used to initiate and control a sustained nuclear chain reaction, used at nuclear power plants to generate electricity and in propulsion of ships. The heat generated from a nuclear fission is passed to a working fluid (water or gas), which runs through steam turbines. They either serve as a ship's propellers or help to turn electrical generators. Some reactors also serve to produce isotopes for medical and industrial uses, or for production of weapons-grade plutonium, while some are run only for research.

Note: A typical 1000 MWe reactor can provide enough electricity for a modern city with up to one million people.

4.3.5.1 Types of Reactors

There are different types of reactors. Some of the important reactors are given below:

4.3.5.1.1 Pressurised Heavy-Water Reactor

- A **pressurised heavy-water reactor** (PHWR) is a nuclear power reactor, commonly **using an un-enriched natural uranium as its fuel,** uses **heavy water (deuterium oxide D_2O)** as its coolant and moderator.
- The **heavy-water coolant is kept under pressure, allowing it to be heated to higher temperature without boiling, much as in a typical pressurised water reactor (PWR).**
- While heavy water is significantly more expensive than ordinary light water, it yields greatly enhanced neutron economy, **allowing the reactor to operate without fuel enrichment facilities** (mitigating the additional capital cost of the heavy water) and generally enhancing the ability of the reactor to efficiently make use of alternate fuel cycles.

4.3.5.1.2 Breeder Reactor

It is a nuclear reactor generating more fissile material in fuel than the one consumed. Less than 1% of the natural uranium initiating the fuel cycle is consumed by a normal reactor. On the other hand, a breeder can burn almost all of it (minus re-processing losses); hence the same amount of energy is generated with lesser wastage. Breeders can be designed to use thorium. Two types of breeder reactors proposed include the following.

4.3.5.1.2.1 Fast Breeder Reactor

A fast breeder reactor (FBR) uses fast (unmoderated) neutrons to breed fissile plutonium and possibly higher transuranics from fertile uranium-238. The fast spectrum is flexible enough to breed fissile uranium-233 from thorium, if required.

FBRs have to be used in the *second stage* to support India's long-term goal of utilising its abundant thorium reserves by using the plutonium produced in PHWRs and breeding fissile uranium-233 from thorium. India has the world's largest thorium reserves, which can produce nuclear power for more than 10,000 years or as long as 60,000 years. The world's only FBR is located in Russia's Ural Mountains at the Beloyarsk Nuclear Power Plant in the city of Yekateringburg.

Presently, the prototype fast breeder reactor (PFBR), a fast breeder nuclear reactor having a capacity of 500 MWe, is being constructed at the Madras Atomic Power Station in Kalpakkam, India, and the IGCAR is given the responsibility for the reactor's design. The PFBR is part of the India's three-stage nuclear power programme. Apart from this, the government is also planning to build four more FBRs, and presently the reactor is in final stages to go critical.

Advantages of the FBR Programme in India

1. **Breeding concept:** FBR produces 30% more fuel than it consumes. It can obtain the high-fissile material production that can be used to fuel another reactor. Therefore, it is easy to alter the breeding ratio in the FBRs by enhancing the number of neutrons. FBRs use small cores, which is important to maintain chain reaction, and it does not require moderator for slowing down of neutrons as it uses fast neutrons.
2. **Economic concept:** Due to high operating temperature of the FBRs, they are having high thermodynamic efficiency, which results in reduced thermal pollution to the environment. Moreover, FBRs generate more energy than the conventional thermal power plants such that 3 grams of uranium on fission can produce ten times the energy as generated by a tonne of coal.
3. **Waste management:** In FBRs, the waste management burdens are nearly 200 times less than that of other conventional nuclear reactors. FBRs use the uranium waste from uranium processing plants and used fuel from other conventional nuclear reactors, which easily manages their nuclear waste. Due to the use of reused fuel in FBRs, the mining and processing expense is also minimised.

(Refer **Infographic – Fast Breeder Reactor and India**)

4.3.5.1.2.2 Thermal Breeder Reactor

Thorium-232 produces uranium-233 after neutron capture and beta decay. Thermal breeder reactors (TBRs) use thermal spectrum (moderated) neutrons to breed fissile uranium-233 from thorium (thorium fuel cycle). Since different nuclear fuels behave differently, a thermal breeder is thought commercially feasible only with thorium fuel, which avoids the build-up of the heavier transuranics.

4.3.5.2 Specific to the Indian Context

India has limited uranium reserves and has plentiful thorium reserves. Hence, FBRs are important due to their ability of effective and efficient utilisation of uranium reserves and also play an important role in the exploitation of the country's thorium reserves. Moreover, the uranium-235 used in LWRs is rare on the earth, whereas on the other hand, uranium-238 used in FBRs is abundant on the earth.

Moreover, thorium cannot be straightaway used as a nuclear fuel, but it can breed to give fissile isotopes (U^{233}) by placing a blanket. Further, premature introduction of thorium at a particular stage can result in a very low generation of peak power load. Hence, the use of thorium has to be carried out in a timely manner in order to accelerate growth in the next stage.

4.3.6 Components of a Nuclear Reactor

There are several components common to most types of reactors.

4.3.6.1 Fuel

Most common fuel used inside reactors are uranium, plutonium and thorium. Uranium is highly used worldwide for power generation.

Distribution of uranium worldwide: First rank – Australia (one-third uranium of the world), Second rank – Khazakhistan (12%) and Third rank – Canada (8%).

4.3.6.2 Moderator

Moderators are used to slow down the emitted neutrons, which have a high velocity range. Some common moderators are **graphite, heavy water, beryllium, beryllium oxide** and **some organic liquids.** Slowing down neutrons is also called thermalisation of the neutrons. Heavy water (D_2O) is one of the best moderators.

4.3.6.3 Control Rods

The control rods are used in initiating and stopping the nuclear fission reactions of the nuclear reactor. Due to large absorption cross-sectional area, **cadmium (Cd)**, **boron (B)** and **Indium (In)** rods are used as control rods. When control rods are inserted in the reactor unit, they absorb the fast-moving neutrons and the chain reaction ceases.

4.3.6.4 Coolant

A coolant removes the tremendous amount of heat developed inside the reactor core. Through a heat

FAST BREEDER REACTOR AND INDIA

- As a part of the Second Stage, India started the **FBR programme with the Fast Breeder Test Reactor (FBTR)**, at **IGCAR, Kalpakkam**.
- This reactor, operating with indigenously developed **mixed (U+Pu) carbide fuel**, has already yielded a large volume of operating experience and a better understanding of the technologies involved.
- This has enabled India to design **500 MWe (prototype)** FBR that will **utilize plutonium and the depleted uranium from their PHWRs.**
- In FBRs, **plutonium-239 experiences fission**, producing energy. On the other hand, the mixed oxide fuel carrying U-238 transforms to extra plutonium-239. Hence, **the stage-two FBRs are intended to 'breed' additional fuel than their consumption**.
- After the building of plutonium-239 inventory, thorium in a reactor is used as a blanket material and transformed to U-233. The U-233 so produced can be used in the third stage.
- **There are four countries in the world that currently have operating fast breeder nuclear reactors: China, Japan, India and Russia.**
  - Recently, Russia has commenced operation of BN-800 (800 MWe capacity).
  - China has started a test reactor of 65 MWt capacity in 2010.
  - Other two reactors JOYO, MONJU in Japan have been shutdown.

exchanger, the coolant transfers heat to the secondary thermal system of the reactor. Water, steam, helium, CO_2, air, molten metals etc. are used as a coolant.

4.3.7 List of Reactors

A total of six main types of reactors (see **Table 4.2**) have been developed worldwide. PWR is very common among them and highly used. Approximately 450 reactors are working worldwide 50% of which are PWRs.

TABLE 4.2 Different Types of Reactors

Reactor Type	Fuel	Moderator	Coolant
Pressurised water reactor (PWR)	Enriched UO_2	Water	Water
Boiling water reactor (BWR)	Enriched UO_2	Water	Water
Pressurised heavy-water reactor (PHWR)	Natural UO_2	Heavy water	Heavy water
Gas-cooled reactor (GCR)	Natural U, enriched UO_2	Graphite	Carbon dioxide
Light water graphite reactor (LWGR)	Enriched UO_2	Graphite	Water
Fast breeder reactor (FBR)	PuO_2 and UO_2	None	Liquid sodium

4.3.7.1 Nuclear Energy Parks (Future Reactor)

These are those places where nuclear power plants are set up for energy generation (**Table 4.3**). Various nuclear energy parks will be established in the future to fulfil the nuclear vision of India (**Table 4.4**).

TABLE 4.3 India's Operating Nuclear Power Reactors

Reactor	State
Tarapore	Maharashtra
Kaiga	Karnataka
Kakrapar	Gujarat
Kalpakkam	Tamil Nadu
Narora	Uttar Pradesh
Rawatbhata	Rajasthan
Kudankulam	Tamil Nadu

TABLE 4.4 List of Future Reactors

Reactor	State
Kudankulam	Tamil Nadu
Jaitapur	Maharashtra
Mithivirdi (or Chhaya-Mithivirdi)	Gujarat
Kovvada	Andhra Pradesh
Haripur	West Bengal

Reactor	State
Kumharia or Gorakhpur	Haryana
Bargi or Chuttka	Madhya Pradesh
Markandi (Pati Sonapur)	Odisha
Bhimpur	Madhya Pradesh
Madras	Tamil Nadu
Mahi Baswara	Rajasthan

(Refer Infographic – Nuclear Power Plants in India)

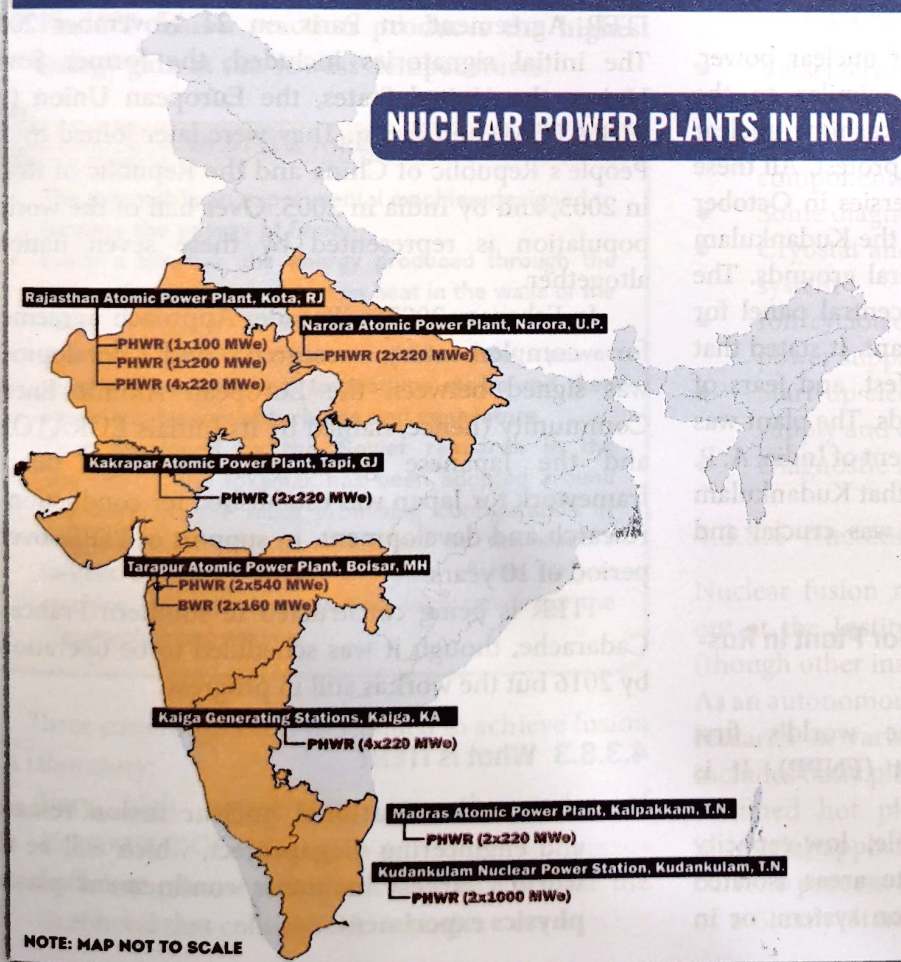
4.3.7.2 Proposed Jaitapur Nuclear Plants

An agreement was signed on 6 December 2010 to construct a first set of two third-generation Europe-based pressurised reactors. During this agreement, the former French President Nicolas Sarkozy and the former Indian Prime Minister Manmohan Singh were present. The proposal is for construction of six European pressurised reactors, designed and developed by France, each of 1650 megawatts, thus totalling 9900 megawatts. These accord as the third-generation PWRs. If built, it would accord to be the largest nuclear power generating station in the world by net electrical power rating. However, it has largely been protested by locals and environmentalists who are concerned about the loss of land, the danger of radiation and destruction in the ecologically sensitive Western Ghats region.

4.3.7.3 Kudankulam Nuclear Power Plant

Kudankulam Nuclear Power Plant (KNPP) is a nuclear power station currently under construction in Kudankulam in the Tirunelveli district of the southern Indian state of Tamil Nadu. On 20 November 1988, an Inter-Governmental Agreement on the project was signed by the then Prime Minister Rajiv Gandhi and the then Soviet President Mikhail Gorbachev, for the

NUCLEAR POWER PLANTS IN INDIA


NUCLEAR POWER PLANTS IN INDIA
Rajasthan Atomic Power Plant, Kota, RJ
PHWR (1x100 MWe)
PHWR (1x200 MWe)
PHWR (4x220 MWe)
Narora Atomic Power Plant, Narora, U.P.
PHWR (2x220 MWe)
Kakrapar Atomic Power Plant, Tapi, GJ
PHWR (2x220 MWe)
Tarapur Atomic Power Plant, Boisar, MH
PHWR (2x540 MWe)
BWR (2x160 MWe)
Kaiga Generating Stations, Kaiga, KA
PHWR (4x220 MWe)
Madras Atomic Power Plant, Kalpakkam, T.N.
PHWR (2x220 MWe)
Kudankulam Nuclear Power Station, Kudankulam, T.N.
PHWR (2x1000 MWe)
NOTE: MAP NOT TO SCALE

- The operation phase of a nuclear power plant is generally the longest phase of its life cycle. **Presently, India has 22 operating reactors**, with an installed capacity of **6780 MWe**. Among these **18 reactors are Pressurised Heavy Water Reactors (PHWRs)** and **4 are Light Water Reactors (LWRs).**

construction of two reactors. The project remained in limbo for a decade, owing to the political and economic upheaval in Russia after the post-1991 Soviet breakup. On 14 January 2004, a small port became operational in Kudankulam. In 2008, the negotiations initiated in building four supplementary reactors on the location. Their capacity has not yet been declared; however, the expected capacity of each reactor will be around 1000 megawatts or 1 gigawatt, thereby bringing the total plant capacity to 9200 megawatts or 9.2 gigawatts.

4.3.7.3.1 Technical Description of Kudankulam Nuclear Plant

The Nuclear Power Corporation of India Limited (NPCIL) and Atomstroyexport are in the process of constructing two 1-gigawatt reactors of the VVER-1000 model (Voda Voda Energo Reactor – A Russian Reactor). One has been commissioned, and the second reactor is under construction. Both units are water-cooled, water-moderated power reactors.

4.3.7.3.2 Controversy with the Kudankulam Nuclear Plant

Fearing the environmental impact of nuclear power, radioactive waste, nuclear accident similar to the radiation leak in March at Japan's Fukushima nuclear disaster were the reasons behind this protest. All these incidents contributed to the controversies in October 2011, which resulted in opposition to the Kudankulam Nuclear Power Plant project on several grounds. The Government of India constituted a central panel for surveying the safety features in the plant. It stated that the Kudankulam reactors are the safest, and fears of the people are not on scientific grounds. The plant was personally visited by the former President of India, A. P. J. Abdul Kalam, and he too reiterated that Kudankulam Nuclear Plant is safe and the plant was crucial and necessary for 'power hungry' India.

4.3.7.4 World's First Floating Nuclear Plant in Russia

- **Akademik Lomonosov** is the world's first **'floating' nuclear power plant (FNPP).** It is coming up in Russia.
- An FNPP is basically a mobile, low-capacity reactor unit operable in remote areas isolated from the main power distribution system, or in places hard to access by land. They are designed to maintain both uninterruptible power and plentiful desalinated water supply in remote areas.

4.3.8 International Thermonuclear Experimental Reactor (ITER)/Artificial Sun Experiment

International Thermonuclear Experimental Reactor (ITER) is a large-scale scientific experiment with the key objective to demonstrate the possibility of producing commercial energy from nuclear fusion.

4.3.8.1 ITER Background and Indian Participation

In 1985, the US President Reagan and the General Secretary Gorbachev of the Soviet Union agreed to pursue an international effort that can help in the development of fusion energy to benefit all mankind, in Geneva, leading to the ITER project.

4.3.8.2 ITER Agreement is Signed

Ministers from the seven ITER members signed the ITER Agreement, in Paris on 21 November 2006. The initial signatories included: the former Soviet Union, the United States, the European Union (via EURATOM) and Japan. They were later joined by the People's Republic of China and the Republic of Korea in 2003, and by India in 2005. Over half of the world's population is represented by these seven nations, altogether.

In February 2007, a 'Broader Approach' agreement for complementary research and development was signed between the European Atomic Energy Community (hence, named by its initials EURATOM) and the Japanese government. Through this, a framework for Japan was established for conduction of research and development, in support of ITER, over a period of 10 years.

ITER is being constructed in southern France at Cadarache, though it was scheduled to be operational by 2016 but the work is still in progress.

4.3.8.3 What is ITER?

- It is **an international nuclear fusion** research and engineering **megaproject**, which will be **the world's largest magnetic confinement plasma physics experiment.**

- It is an **experimental tokamak nuclear fusion reactor** that is being built in **southern France.**
- The goal of ITER is **to demonstrate the scientific and technological feasibility of fusion energy for peaceful use.**
- **The project is funded and run by seven member entities:**
  - The European Union, China, India, Japan, Russia, South Korea and the United States.

What will ITER do?

1. **Produce 500 MW of fusion power**
2. Demonstrate the integrated operation of technologies for a fusion power plant
3. Achieve a **deuterium–tritium plasma** in which the reaction is sustained through internal heating

How is it achieved in the laboratory?

- Most efficient fusion reaction in the laboratory setting is **the reaction between two hydrogen isotopes, deuterium (D) and tritium (T).**
- The **DT fusion reaction produces the highest energy gain at the 'lowest' temperatures.**

WHAT IS A TOKAMAK?

- The tokamak is an experimental **machine designed to harness the energy of fusion.**
- Inside a tokamak, **the energy produced through the fusion of atoms is absorbed as heat in the walls of the vessel.**
- Just like a conventional power plant, **a fusion power plant will use this heat to produce steam and then electricity by way of turbines and generators.**
- **First developed by the Soviet research in the late 1960s,** the tokamak has been adopted around the world as the most promising configuration of magnetic fusion device. **ITER will be the world's largest tokamak** – twice the size of the largest machine currently in operation, with ten times the plasma chamber volume.

Three conditions must be fulfilled to achieve fusion in a laboratory:

1. Very high temperature (on the order of 150,000,000°C)
2. Sufficient plasma particle density (to increase the likelihood that collisions do occur)
3. Sufficient confinement time (to hold the plasma, which has a propensity to expand, within a defined volume)

4.3.8.4 India's Contributions to the ITER Project

All the seven partners will contribute to build ITER, that is, each will build its share of ITER components through an appropriately formed Domestic Agency (DA) and industries and finally deliver them to ITER. The device will be finally assembled. India's contribution, like other partners except the host EU, was about 10% of the ITER construction cost (the EU pays about 40% since the ITER is being built in France and the remaining six members, including India, have to contribute 10% each). Most of this will be in the form of components made by the Indian industry and delivered to ITER, and a small part (1%) is to be paid in cash to a common fund for in-cash procurements by the ITER International Team.

4.3.8.5 India will Deliver Various Components in ITER Research

- Vessel ferromagnetic inserts
- Cryolines and cryo-distribution system
- Heat rejection and water cooling system components
- Some diagnostics systems
- Cryostat and vacuum vessel pressure suppression system
- Ion cyclotron heating and current drive sources, power supplies and control systems
- Start-up electron cyclotron heating source, power supply and control system
- Diagnostic neutral beam

4.3.8.6 Nuclear Fusion Research in India

Nuclear fusion research in India is primarily carried out at the Institute for Plasma Research (IPR), Pune (though other institutions like BARC are involved too). As an autonomous Physics research institute, it involves research in various aspects of plasma science, which includes basic plasma physics, research on magnetically confined hot plasmas and plasma technologies for industrial applications. Besides the basic research, the current process of the institute involves the building of a Steady State Superconducting Tokamak (SST-1).

A tokamak represents a type of nuclear reactor (the ITER will also be a tokamak device). IPR has previously built a tokamak called ADITYA.

CHINA'S 'ARTIFICIAL SUN'/EXPERIMENTAL ADVANCED SUPERCONDUCTING TOKAMAK (EAST)

This project is a part of ITER that will be the world's largest nuclear fusion reactor by 2035. In the next goal EAST project will try to maintain the high temperature for a long period of time. The EAST device will replicate the nuclear fusion process carried out by the sun.

China's 'artificial sun' experiment set a new record after it ran at 120 million degrees Celsius for 101 seconds. For 20 seconds, EAST also achieved a peak temperature of 160 million degrees Celsius, which is over ten times hotter than the sun. This experiment was conducted at the **Institute of Plasma Physics of the Chinese Academy of Sciences (ASIPP)**, in **Hefei**.

The ultimate goal of EAST is to create nuclear fusion experiments like the sun by using deuterium obtained from the sea. Deuterium from one litre of seawater is enough to produce energy equivalent to 300 litres of gasoline through a nuclear fusion reaction.

For nuclear fusion to occur, tremendous heat and pressure are applied to hydrogen atoms so that they fuse together. Unlike fission, nuclear fusion is considered a safer process with no nuclear waste. Nuclear fusion could potentially provide unlimited clean energy at very low costs.

4.3.9 Advantages and Disadvantages of Nuclear Energy

4.3.9.1 Advantages of Nuclear Energy

- Currently, the world derives 12–18% of the world's electricity through nuclear energy because of its advantages in terms of greenhouse gases. Greenhouse gases (carbon dioxide, methane, ozone, chlorofluorocarbon) are not released during nuclear reaction.
- Even a small amount of uranium generates huge energy through fission. As per current estimates, the reserves of uranium found on the earth may last for another 100 years. A single nuclear power plant can generate high amount of energy; also, nuclear fuel is comparatively inexpensive and can be transported easily.

4.3.9.2 Disadvantages of Nuclear Energy

- Nuclear energy can lead to the production and proliferation of nuclear weapons; hence, fission, fusion or combination of both reactions can be misused for destructive purposes. This proves them to be a major threat to the world, causing large-scale devastation.
- A nuclear power plant requires large capital cost and is time consuming as well. Around 15–20 years are taken to develop a single plan thereby proving it not to be feasible. The functioning of nuclear reactor is possible only till the availability of the uranium.
- The fission reactions produce wastes containing unstable elements that are highly radioactive, proving them dangerous to the environment as well as human health, and their after effects also remain so, for thousands of years.
- Professional handling is mandatory for the nuclear reactor and it needs to be isolated from the living environments. Since, over a period of time, the radioactivity gets reduced, after decaying, there is a need for adequate and effective storage practices. The radioactivity of these elements reduces over a period of time.
- The Chernobyl disaster of 1986 in Ukraine was the worst nuclear power plant disaster. Hence, there stands the possibility of such disasters in future.

4.3.10 Radiation and Radioactivity

Radiation is the term referring to the propagation of particles and waves through space and includes both electromagnetic radiation and atomic and subatomic particle radiation; it was first discovered by Becquerel in 1986 during experiment on fluorescence of uranium.

Electromagnetic radiation has a broad, continuous spectrum of energy that includes visible light, radio waves, microwaves, gamma rays, X-rays, even the infrared and ultraviolet radiations. The neutrons, alpha and beta particles, protons and heavy ions are all included in the particle radiation. The energy and speed of the particle radiation depends upon the radiation source and any subsequent interaction between the particle and other matter.

For diagnosis and treatment of certain diseases or illness, radiation can also be generated. Besides, they

can also be applied to eliminate or reduce harmful microorganisms as well as enhance the safety of the medical equipment, even the food supply, cooked food and in transmitting information (radio, cellular phones, television etc.).

Radioactivity, as a term, refers to the property of spontaneous emission of electromagnetic radiation of particles, shown by certain materials. The unstable atoms, while undergoing transition to a more stable state, emit these radiations. This transition is termed as radioactive decay. Naturally existing unstable atoms are said to be naturally radioactive. Examples of such naturally radioactive atoms include carbon-14, radon-222, potassium-42, uranium-235, uranium-238 and thorium-232. In addition to these, radioactive atoms can be produced when an interaction is conducted between the nucleus of an atom and a particle or electromagnetic radiations to produce an unstable nucleus. This process is typically conducted in nuclear reactors and particle accelerators.

4.3.10.1 Radioactive Decay Law

On emission of alpha and beta rays, which are usually but not invariably accompanied by gamma emission, the emitting parent nuclide transforms into a new daughter element; the daughter element may be again radioactive so that the process of successive disintegration continues till the original active parent nuclide gets transformed into a stable one.

According to the decay law, the number of active nuclides decreases exponentially with time. Therefore, an infinite time is theoretically needed for the complete disintegration of a radio element and in this respect, all radio elements are the same. The radioactive atoms undergo the transition to a stable state by emitting radiation in several forms as follows:

- As charged particles (like alpha particles, beta particles and positrons)
- As uncharged particles (neutrons)
- As electromagnetic radiation (gamma rays and X-rays)

4.3.10.2 Sources of Radiation

Most of the radiations are received from the cosmic radiation and the sun. Thus, the individuals at higher elevations such as states of Colorado and adjacent Rocky Mountain receive comparatively greater radiation than those living at sea level. Besides this, many radiations are also derived from the rocks and soil around us.

4.3.10.3 Benefits of Radiation

Humankind can utilise radiation and radioactive materials in a number of ways:

1. **Agriculture:** There has been tremendous increase and improvement in the volume and quality, respectively, of grains as well as cereals by growing superior strains that are labelled by radioactive isotopes. Hence, they proved to be effective measures in alleviating famine in third-world countries.
2. **Environmental measurements:** Radioactive isotopes can greatly be utilised for the accurate measurement of movement of pollutants through the environment including its groundwater and rivers.
3. **Eradication of pests:** There is a drastic fall in the population of pests due to the sterilisation of male flies due to radiation.
4. **Food:** Food, such as chicken and beef, being sterilised through irradiation shows an increased shelf life and is also *E. coli*-free, which is a bacterium known to have taken the lives of many children due to the consumption of badly cooked fast-food hamburgers. The food irradiation extension could prove a saviour in such cases for many children and would be particularly of great help to the developing countries with less adequate refrigeration.
5. **Generation of electricity:** Nearly 440 nuclear plants in and around the world have been reported to contribute around 16% of the world's electrical energy needs.
6. **Medical diagnostics:** The radiation uses have provided greater help from X-rays, through magnetic resonance imaging along with the usage of radioactive tracers, in order to diagnose various conditions like fault in thyroid glands or problem in bones. Moreover, the radioactive tracers have been known to replace invasive surgical diagnosis.
7. **Oil drilling:** There are wide uses of isotopes for measuring the steam quality before infusing into almost obsolete wells of oils so as to force out the residual supplies.

8. **Polymerisation of plastics:** It can be done through irradiation instead of the usage of destructive heat treatments.
9. **Quality control of metal parts:** Relying on metal parts such as the aircraft blades or turbines can be confirmed through radiophotography on a conveyor rather than destroying a blade's sample so as to ensure their intactness.
10. **Research in biology:** The usage of radioactive tracers enables the non-invasive elements and drugs tracking in the body, both for medicine and for studying metabolism.
11. **Space power:** When there is a requirement of small amounts of power in space, especially in regions of insufficient solar power (on the dark side or in regions where large solar panels are impossible), the ideal compact energy producers are plutonium batteries.
12. **Treatment of cancer:** Radioactivity can selectively kill cancerous cells, either in the direct beam form such as for breast cancer, or in the form of bullets of radioactive material, which are considered in the direct migration to the cancerous cells that need to be killed. The chemotherapy, being the sole alternative, involves the usage of invasive drugs, and is considered a difficult option for the patient.

Thus, the advantages of radiation continue. Hence, it can be concluded that for many aspects of our daily life, our society greatly depends on its assistance.

4.3.11 Nuclear Winter

Nuclear winter, as the theory describes, is the climatic effects of nuclear war. The smoke from the fires started by nuclear weapons, mainly the sooty, black smoke from cities and industrial areas, would get heated by the sun, lofted into the upper stratosphere and thus spread globally, making it last for years. This results in a cool, dark, dry condition at the earth's atmosphere because it does not allow the sunlight to enter into the atmosphere, which would prevent crop growth at least for one growing season, resulting in mass starvation in the world.

Most frequently, it is suggested to manifest, as a result of the combined combustion and pollution from the burning of areas that are at least the size of 100 cities, at the intensity of a fire storm, wherein the smoke remained for years and thus caused temperature drops for as long as it remained, and this is what we called 'nuclear winter'.

4.3.11.1 History

On 6 August 1945, a 15-Kt (kilotons) nuclear bomb was dropped on Hiroshima, Japan, killing 1,50,000 people at a time. Many of them died due to fires ignited by the bomb, which turned the city into a raging inferno and formed dense blackish clouds in the atmosphere. And then, three days later, another 20-Kt bomb was detonated on Nagasaki, Japan. This huge cloud formation cooled the global climate by 1°C and it produced a 'small nuclear winter'. In March 1991, due to Iraq's invasion of Kuwait, the smoke released due to the fires set to the oil reserves plumed to the stratosphere, serving as one of the main contributors to formation of soot, because the smoke from oil had a higher ratio of black soot, thus absorbing more sunlight.

4.3.11.2 Consequences

- **Biological consequences:** Most important consequence of a nuclear winter for humankind is food crisis. This comes from environmental disruption that wipes away agricultural production completely. As the soot released on the earth moves to the stratosphere, it blocks the sunlight from reaching the earth. Without sunlight, there would be no rain, no lifecycle happening on the earth's surface. Due to decrease of the earth's climatic temperature, there is no single chance of growing crops, therein resulting in a food crisis.
- **Ozone depletion:** A 2008 study by Michael J. Mills found that nuclear weapons exchange between India and Pakistan using their arsenal could create an ozone hole. So, the UV rays of sunlight could enter the earth's atmosphere, leading to depletion of human health, including causing harm to the flora and fauna. The urban fires released as much as five million metric tonnes of soot into the mesosphere during the bomb explosion in Hiroshima and Nagasaki, causing a series of surface chemistry reactions on the earth's atmosphere.
- **Nuclear summer:** It is just like a hypothetical scenario after a nuclear winter has generated a greenhouse effect because of the CO_2 released

by combustion of methane and those released from the decay of organic matter. This methane will freeze during the nuclear winter period and cannot go outside. So global warming increases afterwards. For example, as per a study conducted in Canada, it was shown that with summer temperature only 3°C below normal, spring wheat production would halt. Colder temperature means shorter growing season and slower maturation of crops which results in much lower yields. Hence, most of the world's people are threatened due to starvation following a full-scale nuclear war. The food deficiency can result in many factors such as trauma, malnutrition, burns, psychological stress and UV-B radiations.

- **Mitigation techniques:** A number of solutions have been proposed to mitigate the potential harm of a nuclear winter. They include producing food without sunlight – some natural digesting bacteria, which are naturally gas digesting, mushrooms-like edible fungi that can grow directly on wood without sunlight. All these foods are very proteinaceous. Some cellulosic biofuel, which also produces sugar, can be implemented.
- **Fire control:** Various methods can be used to control fire during a nuclear war such as dry ice shower, liquid nitrogen etc.
- **Policy implications:** The suicidal nature of using nuclear weapons marks one of the most important policy imperfections. It means that if one country uses enough weapons in military against another country, then the climatic consequences could be such that everyone in both the countries could die. Nuclear weapons, therefore, become suicidal weapons and not for preventions. The only solution can be to reduce the number of weapons to such a level that will still provide a deterrent, but without resulting in a nuclear winter. Britain, China and France have had arsenal weapons for many years, and the number they have deemed is more than sufficient to maintain credible defence of their countries.

4.3.12 Nuclear Medicine

The branch of medicine that deals with the use of radioactive substances in treatment, research and diagnosis is called as nuclear medicine.

The small amounts of radioactive materials used in medicine are known as radiotracers. These radiotracers are typically injected into the blood vessel, i.e., vein, inhaled or swallowed as capsules. The radiotracers travel through the area being examined and by dissolving directly in blood it gives off gamma rays. These gamma rays are detected by specific camera and computer, so as to create images of the inside of body and identify the disease.

4.3.12.1 History

The father of nuclear medicine is John Lawrence. In 1936, he made the first application in patients of an artificial radionuclide by using phosphorous-32 for treatment of leukaemia. Due to successful treatment of the patient with thyroid by use of Iodine-131, nuclear medicine gained public recognition as a potential specialty on 7 December 1946. Among many radionuclides that were discovered for medical use, the most important discovery and development was Technetium-99m. C. Perrier and E. Segre discovered it in 1937 as an artificial element in order to fill space number 43 in the periodic table.

Today, it is the most utilised element in nuclear medicine.

4.3.12.2 Diagnosis

Depending on the types of nuclear medicine exam, a dose of radio tracer is injected into the vein or swallowed or inhaled as gas. It may take from 20 minutes to several hours or days to travel through the body. After reaching its destination, it gives off gamma rays and is detectable by specific cameras, which take a series of images. The end result of the nuclear medicine imaging is a data set having one more image. In a multi-image data set, the array of images repeat a sequence called 'cardiac gate time sequence' or 'spatial sequence'. Areas of greater radiotracer intensity are called as hot spots, indicating high metabolic rate. Less intensity areas are called as cold spots, indicating low metabolic rate.

In radioactive iodine therapy for thyroid disease, radioactive iodine (I-131) is swallowed or injected into the gastrointestinal tract and is concentrated by the thyroid gland when it kills the cell.

4.3.12.2.1 Uses of Imaging Procedure in Varied Areas

Doctors use radionuclide imaging procedures to identify the structure of organs, their functions, bone and systems.

- **Brain:** It detects the early stage of Alzheimer's disease. It evaluates chemical disorder of Parkinson's disease. It provides an idea of the stages of tumour, surgical or radiational planning. It investigates disorders such as memory loss, abnormality in blood flow inside the brain, seizures etc.
- **Lungs:** It helps to detect lung transplant rejection. It scans lungs for respiratory and blood flow problems.
- **Heart:** It assesses the damage to the heart, following a heart attack. It evaluates treatment options such as bypass surgery and angioplasty. It detects heart transplant rejection. It evaluates spinal fluid flow and potential spinal fluid leaks.
- **Cancer:** Nuclear medicine helps in determining the presence and spread of cancer in various parts of the body. Doctors can plan for treatment by use of these medicines. It localises sentinel lymph nodes before the surgery in patients with breast cancer or skin as well as soft tissue tumours. In children, nuclear medicine is also used while investigating abnormalities in the oesophagus like oesophageal reflux or mortality disorders and helps in the evaluation of openness of ventricular shunts in the brain. Nuclear medicine therapies include radioactive antibodies used for treatment of certain cancer of the lymphatic system. I-131 MIBG is used to treat adrenal gland tumours in adults and nerve tissue tumours in children. It is used to treat painful tumour metastasis to the bones.

4.3.12.2.2 Benefits

For many diseases, nuclear medicine scans yield the most useful information needed to determine appropriate treatment. Nuclear medicine offers the potential to identify the disease in its earliest stage. PET (positron emission tomography) scans provide information that is helpful in radiation therapy, i.e. chemotherapy planning. PET scans identify the best biopsy location. It provides information about both function and anatomic structure of the body.

4.3.12.2.3 Risks

The nuclear medicine diagnostic procedures have been in use for more than five decades and so far no long-term adverse effects due to such low dose exposure are known. Allergic reactions to radiopharmaceuticals may be possible but are extremely rare and mild. Nuclear medicines are time consuming and can take several days. Also, the resolution of structures of the body with the nuclear medicine may not be as high as with the other imaging techniques such as CT and MRI. It is a very sensitive procedure compared to any other techniques. It is possible that a nuclear stress test could cause heart attack.

5.1 THE INTERNATIONAL ATOMIC ENERGY AGENCY

The **International Atomic Energy Agency** (IAEA) serves as an intergovernmental forum for scientific and technical cooperation in the peaceful use of nuclear technology and nuclear power worldwide. **It was set up as the world's 'Atoms for Peace' organisation in 1957 within the United Nations family.** The agency works with its Member States and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies.

It seeks to promote the peaceful use of nuclear energy, and to inhibit its use for any military purpose, including nuclear weapons. The **IAEA reports to both the United Nations General Assembly and Security Council.** The IAEA has its headquarters in **Vienna, Austria.**

5.1.1 Scope of Safeguards

They prevent nuclear proliferation just like procedures of auditing for confidence building for having appropriate financial conduct, thereby preventing embezzlement. Specifically, they aim to validate if the nuclear material, which is declared, remains inside the established nuclear civil fuel cycle and its application is exclusively for peaceful purposes or not.

5.1.2 Aim of the IAEA

Conventional IAEA protection aims for the discouragement of nuclear material diversions for its usage in peaceful manner and hence, to maximise its early detection risk. The safeguards, thus, serve both the international community and individual states. Recognising it, by showing compliance with these commitments, will benefit them.

The inspections function as a vigilant system that warns the likely nuclear material diversion from peaceful activities. Such a system relies on the following:

- **Material Accountability** – Collection and investigation of the nuclear material, on-site assessment, reassessment and substantiation of the functional records all come under material accountability.
- **Physical Security** – The nuclear materials access is confined at the use of its site, beyond which it is not permitted.
- **Containment and Surveillance** – Closures, automatic cameras and other such instruments are used for detection of unwanted shifting or tinkering with the materials, besides site spot checks.

Note: The five states, with weapons, and the non-NPT states such as India, Pakistan and Israel come under facility-specific safeguards application for the applicable plants. The IAEA inspectors regularly visit these facilities to keep an eye on any possible inconsistency in the records.

5.2 ADDITIONAL PROTOCOL

The Additional Protocol is a safeguard agreement that serves as the legal document of the IAEA safeguards agreement (as a tool for verification). As per this, the IAEA has the corresponding legal power for verification of a state's safeguard commitments. Hence, the Additional Protocol is intended for all the states with any kinds of safeguards agreement. **The Comprehensive Safeguards Agreements (CSAs) is involved in deciding to settle as well as take action for the additional protocols.**

5.2.1 Status of the Additional Protocol

As of November, 2022 Additional Protocols are into force with 140 states and Euratom (European Atomic Energy Community), and another 13 states are yet to bring it into force.

5.2.2 Goal of Additional Protocol

The IAEA has granted the extended rights to access information and sites through Additional Protocol. The primary aim of the additional protocol is to seal the breaks in the information, given under the CSAs.

5.2.3 Strengthening Measures Under the Additional Protocol

States with CSAs need to equip the IAEA with important supplementary substantiation measures. Such measures delivering broader access to information regarding the nuclear programme of the states, increases physical

access by the IAEA as well as improved administrative measures.

5.2.4 Additional Measures

- Information to be provided by states, regarding all parts of its nuclear fuel cycle, ranging from uranium mines to the nuclear waste and other locations where the nuclear material intended for non-nuclear use is present;
- Information to be provided by states regarding all buildings on a site;
- Information to be provided by states regarding its nuclear fuel cycle, research and development activities that are not concerning nuclear material;
- Information to be provided by states regarding the production and trade of sensitive nuclear-related equipment and material, and access of IAEA to production and import locations of the states;
- IAEA examination of environmental samples outside the acknowledged locations, when deemed essential by the IAEA;
- A streamlined system for designation of IAEA inspectors, and the issuance of multiple entry/exit visas as well as IAEA use of internationally recognised systems of communications.

According to the Additional Protocol, the IAEA can carry out complementary sweeping in order to be assured of the absence of undeclared nuclear material and the activities, to resolve any inconsistency regarding the information provided by a state, as well as to confirm the decommissioned status of any facility or Location Outside Facilities (LOFs) like hospitals where nuclear material was usually used.

5.3 INTERNATIONAL TREATIES AND ARRANGEMENTS FOR THE NUCLEAR TECHNOLOGY

5.3.1 Nuclear Non-proliferation Treaty

5.3.1.1 NPT Origins

The IAEA has been playing a vital role in the form of safeguards system, over the past 35 years, under the Nuclear Non-proliferation Treaty (NPT). This safeguards system is a noticeable international success in the course of cutting the civil uranium diversion into the military usage. Its chief feature is the collaboration with the nuclear energy development and further ensuring the usage of plutonium, civil uranium and associated plants are only for peaceful purpose. The NPT was extended indefinitely in 1995, and it leads to widening its scope for inclusion of undeclared nuclear activities.

Nuclear weapons have been renounced by many nations, since they acknowledge the fact that the possession of such weapons would threaten, instead of enhancing the national security. They have, thus, embraced the NPT in the form of a public obligation for the peaceful usage of the nuclear materials and technology.

In the year 1968, a milestone achievement in the non-proliferation history was observed with the successful conclusion of negotiations of the NPT. After being enforced in 1970, its indefinite extension in May 1995 was the other landmark achieved. Essentially, it was an agreement among the five nuclear weapons states and included other countries that were interested in nuclear technology. The deal was on the grounds that the assistance and cooperation would be traded for pledges, which will be backed by international scrutiny, directing that no plant or material would, in any case, be diverted to weapons use. States or parties refusing to be a part of the deal would not be included from international cooperation or trade that involves nuclear technology.

5.3.1.2 Members and Non-Members

As per the current status, 191 states are NPT parties, inclusive of all declared Nuclear Weapons States' (five states). These five states had tested a nuclear missile before the year 1967; they are France, China, the United Kingdom, the United States and the Russian Federation. The major countries which remain outside the NPT are Pakistan, Israel and India. They all are equipped with nuclear programmes which have approached to maturity since the year 1970. Hence, they first need to renounce and dismantle their nuclear weapons in order to join NPT membership. For India, internationally particular arrangements were agreed, in the year 2008, taking it half-way, and its further ratification of the Additional Protocol in 2014 places it on a similar footing to the five NWS.

KEY POINTS

The NPT is a multilateral treaty, aimed at limiting the spread of nuclear weapons including three elements:

1. Non-proliferation
2. Disarmament
3. Peaceful use of nuclear energy.

These elements constitute a 'grand bargain' between the five nuclear weapon states and the non-nuclear weapon states. The treaty was signed in 1968 and entered into force in 1970. Presently, it has 191 member states.

Implications

1. States without nuclear weapons will not acquire them.
2. States with nuclear weapons will pursue disarmament.
3. All states can access nuclear technology for peaceful purposes, under safeguards.

Key Provisions

1. ***The Treaty defines Nuclear Weapon States (NWS)*** as those that had manufactured and detonated a nuclear explosive device, prior to 1 January 1967. All the other states are, therefore, considered ***Non-Nuclear Weapon States (NNWS).***
2. ***The five Nuclear Weapon States are*** China, France, Russia, the United Kingdom and the United States.
3. ***The Treaty does not affect the right of state parties to develop, produce and use nuclear energy for peaceful purposes.***

Role of States

1. Nuclear Weapon States are not to transfer to any recipient whatsoever nuclear weapons and not to assist, encourage, or induce any NNWS to manufacture or otherwise acquire them.
2. Non-Nuclear Weapons States are not to receive nuclear weapons from any transferor, and are not to manufacture or acquire them.
3. NNWS must accept the IAEA safeguards on all nuclear materials on their territories or under their control.

India declined to sign the NPT because of the following reasons.

1. As per the NPT, the countries which tested nuclear devices before 1967 are termed as 'nuclear weapons states', which India cannot be a member of.
2. There was no mention of any fixed timelines for disarmament.
3. The NPT is an unjust treaty, as there was no obligation of nuclear weapon states for giving them up while non-nuclear states are not allowed to have them.

5.3.1.4 India's Emergence as *de facto* Weapons State Under NPT

Being a nuclear-armed country, India could not join the NPT. As per the current state of India and the associated lack of full-scope IAEA safeguards, it was pointed that India faced insult from the world trade by the Nuclear Suppliers Group; however, a clean chit to the trade restraint got approval in September 2008, as recognition to its impeccable non-proliferation credentials.

A regulation was passed in the US Assembly, in December 2006, enabling nuclear trade with India and consequently, a nuclear collaboration accord was concluded with India in July 2007. This opened new means to enable the country's involvement in international business in nuclear equipment and fuel. As a result, India was required to lay mostly its nuclear power reactors under the safeguards of the IAEA and shut down the CIRUS research reactor by the year 2010, finally enabling the country to recycle the US-originated nuclear fuel that is sourced from other foreign countries at the new plant, under the safeguards of the IAEA. Hence, the fuel already used occurring from the 14 reactors is nominated as clearly civilian and under the full safeguards of the IAEA.

The deal was accepted by the IAEA as a form of 'a creative break with the past' wherein the country was barred from the NPT. It faced much deferment in the country's Parliament, and ultimately, a fresh as well as safeguards agreement in a comprehensive manner by the IAEA, with a supplementary Protocol, was set up. An agreement was sanctioned by the board of the IAEA, in the year July 2008, after it had endangered to topple down the government. This accord is same as that among the non-nuclear weapons states and the IAEA, particularly **INFCIRC 66**.

Next came the unanimous resolution of the 48-member NSG for exempting India from trade prohibition with the NPT non-members. A trade joint agreement was, thus, made to the US Congress for its final sanction, which was followed by France and Russia. Mapping India, in level with China, along with its accountabilities and trade prospects is the primary aim behind it.

The introduction to safeguards agreement of India with the IAEA states access of India to assured

deliveries of fresh fuel to be an 'essential basis' for the acceptance of the states of IAEA safeguards on certain areas of its reactors and that it is rightful to undertake curative measures to that, ensuring its nuclear civil reactors non-stop operation, in case there is foreign fuel supplies distraction. Besides this, it also states that India will 'give reassurance against the safeguarded nuclear material withdrawal from the civilian usage at any time'. Assurances about weapon testing were also provided during the course of the NSG.

A nuclear trade agreement was contracted between India and France in October 2008 after the bill sanctioning civil nuclear trade with India was passed by US.

In early 2009, the safeguards agreement was signed between India and the IAEA, although the time-frame to get the extra reactors under safeguards was yet to be finalised. The IAEA Board agreed upon the Additional Protocol to the safeguards agreement in March 2009. India signed the same in May 2009, that is, a couple of months later. The new government announced the approval with a list of 20 facilities that includes six at the Nuclear Fuel Complex, Hyderabad and the two stores at Tarapur and 12 reactors in June 2014. The enforcement of the Additional Protocol was carried out on 25 July 2014, providing the IAEA heightened access to civil power facilities of India.

Thereafter, the UN Security Council was told by India that given its capability and inclination for the objectives of non-proliferation of the world, **it has obeyed the guidelines of the NSG as well as the Missile Technology Control Regime (MTCR).** India, as a country with the capability and willingness for promoting global non-proliferation objectives, believes that the next logical step is membership of India of the four export control regimes. **The other two 'regimes' include the informal Australia Group (re-chemical and bio-weapons) and the Wassenaar Arrangement on export control for the conventional arms and dual-use goods and technologies.** Not only this, India also backs the early commencement of the discussions in the Conference of Disarmament on a **Fissile Material Cut-off Treaty in Geneva.** Moreover, India will pursue association with the four export control regimes, in the course of following the sanctions of the Additional Protocol.

Besides the safeguards, a primary intent of the Fissile Material Cut-off Treaty is capping the weapons-grade fissile materials generation in the NPT Nuclear Weapons States as well as India, Pakistan and Israel. The country, such as India, has articulated its backing for a Cut-off Treaty, while the opposition is from China, Pakistan and Iran. The United States though is not keen on such a treaty being verifiable.

5.3.2 Nuclear Suppliers Group

It is a multilateral control regime group and nuclear supplier countries group, which identify to contain nuclear proliferation through the curbing of materials, equipment and technology exports used in the manufacturing of nuclear weapons. Currently, the NSG has 48 members, including five nuclear weapon states such as the United States, the United Kingdom, France, China and Russia. It is not a formal organisation, and its guidelines are non-binding in nature and membership decision for any nation can be made with censuses.

- Hence, India conducted its first nuclear test, Pokhran-I (Operation Smiling Buddha), in May 1974, under the leadership of Prime Minister Indira Gandhi.
- The nuclear powers were convinced that the nuclear NPT alone would not be sufficient to contain the spread of nuclear weapons and accordingly, the **NSG was formed in 1974.**
- As per the current guidelines of the NSG, a country cannot be a member of the NSG if it is a non-NPT state, thereby, keeping India out of the group.
- In the year 1998, India again conducted the second nuclear test named under Operation Shakti termed as 'Pokhran-II'. However, new sanctions were imposed on India by Western countries, especially the United States.
- Pre-2005, the NSG was starved of fuel of the Tarapur Atomic Power station, while the United States used MTCR regulations to thwart the cryogenic engine technology transfer from Russia.
- In the year 2008, the country got a little help when it agreed to the Indo-US **civil nuclear deal,** in which India signed a civil-military separation plan and India-IAEA safeguard agreement and in return, the US diplomacy managed to get India an NSG waiver.

NUCLEAR DIPLOMACY

1945

The Nuclear Bomb was dropped in Hiroshima and Nagasaki in 1945.

- Atomic bombings of Hiroshima and Nagasaki occurred during World War II
- Hiroshima was bombed on August 6, 1945, causing massive destruction and an estimated death toll of 140,000
- Nagasaki was also bombed on August 9, 1945
- The bombings played a role in Japan's surrender and the end of the war

1968

NPT

The NPT was opened for signature in 1968 but entered into force in 1970. [Nuclear weapon states are those that have tested nuclear explosive device before 1 January 1967. These nations are the United States, Russia, the United Kingdom, France and China]

- The Non-Proliferation Treaty (NPT) aims to prevent nuclear weapon proliferation.
- It entered into force in 1970 and has widespread membership
- The NPT has three pillars: non-proliferation, disarmament, and peaceful nuclear energy use
- Non-nuclear-weapon states commit to not acquiring nuclear weapons, while nuclear-weapon states commit to disarmament
- A total of 191 States have joined the Treaty, including the five nuclear-weapon States. **India have not signed NPT**

1974

NSG

The NSG was founded in 1974 with seven countries (Canada, France, Japan, West Germany, the Soviet Union, the United States and the United Kingdom) and the treaty was signed to prevent nuclear proliferation.

- Regulates nuclear exports and sets guidelines for materials, equipment, and technology
- Consists of **48 member countries. (India is not a member of the Nuclear Suppliers Group)**
- Vital for global non-proliferation and nuclear security
- Curbs the spread of nuclear weapons technology
- Membership grants access to advanced nuclear technologies
- Debate over NSG's membership expansion process

1987

MTCR

The MTCR was established in April 1987 by G-7 Countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) as an informal and voluntary partnership among 35 countries to prevent proliferation of missiles and UAV (Unmanned Aerial Vehicle) technology capable of carrying above 500 kg payload for more than 300 km.

- Voluntary membership based on commitment to non-proliferation of missiles
- Controls transfer of missiles capable of carrying weapons of mass destruction
- Sets guidelines and restrictions on missile exports
- Promotes transparency and non-proliferation efforts
- Regularly updates guidelines and control lists
- Important in curbing the spread of missile technology
- **India became member in 2016**

1996

CTBTO PREPARATORY COMMISSION

The CTBT (Comprehensive Nuclear-Test-Ban Treaty) was adopted by the UN General Assembly on 10 September 1996 but did not enter into force because eight specific states did not ratify it (These are China, Egypt, Iran, India, Israel, North Korea, the United States and Pakistan)

- Adopted in 1996 to ban nuclear explosions
- Aims to prevent nuclear weapons development
- Signatories commit to refraining from nuclear testing
- **185 countries have signed**
- Entry into force requires specific ratifications
- Supports nuclear disarmament
- Some key countries have not ratified

1957

IAEA

IAEA was established as an autonomous organization on 29 July 1957.

- The IAEA is an international organization promoting peaceful nuclear energy use and preventing nuclear weapon proliferation
- It provides technical assistance, inspections, and verification to ensure compliance with nuclear safeguards agreements
- The IAEA supports nuclear safety, security, and cooperation in areas such as cancer treatment and environmental protection
- Total Members- 176 (as on 3rd Jan 2023). **India is its member since 1957**

1974

The Pokhran test was conducted in India on 18 May 1974. [called as "Smiling Buddha" operation and without India signing the NPT, it earned the nuclear development technology]

- Pokhran Test in 1974: India's first nuclear test on **May 18, 1974**
- Codenamed **"Smiling Buddha"**: Fission device using plutonium
- India became the **sixth nuclear-armed state**
- Aimed at advancing civilian nuclear energy programme
- Mixed international reactions: Proliferation and security concerns
- Influenced global disarmament discussions
- India maintains **"no first use" policy**
- Impact on diplomatic relationships and nuclear cooperation
- Implications for export controls and engagements

1985

The Australia Group was established in 1985 as a multilateral export control regime. It is an informal forum of countries which controls export of chemical and biological weapons

- Aims to prevent chemical and biological weapons proliferation
- **Total Members : 43 (India became its 43rd member on 19 January 2018)**
- Coordinates efforts to control sensitive materials and technologies
- Develops and maintains lists of controlled items
- Enhances transparency and information sharing
- Restricts the spread of chemical and biological weapons capabilities
- Voluntary membership based on non-proliferation commitment

1996

WA

The Wassenaar Arrangement, established on 12 July 1996, regulates exports control on conventional arms and dual-use goods and technologies.

- Wassenaar Arrangement: Multilateral export control regime.
- **42 participating states. (Indian became member in 2017)**
- Aims to prevent destabilizing arms and technology transfers
- Sets guidelines for sensitive item exports
- Covers firearms, military equipment, and dual-use technologies.
- Promotes transparency and responsible arms trade
- Regularly updates control lists
- Prevents proliferation to unauthorized end-users
- Voluntary participation based on export control standards

1998

Pokhran 2

- Pokhran 2 refers to a series of nuclear tests conducted by India in **May 1998**
- The tests took place in the Pokhran region of Rajasthan, India
- It was the **second round of nuclear tests by India**, the first being Pokhran 1 in 1974.
- **Five nuclear explosions** were conducted between May 11 and May 13, 1998, under the codename **"Operation Shakti."**
- The **tests included both fission and fusion devices**, demonstrating India's nuclear weapon capabilities

- At the time of visit to India in November 2010, US President Barack Obama announced support for India's participation in the Nuclear Suppliers Group, the Wassenaar Arrangement, the Australia Group and the MTCR, in a phased manner.
- Due to India's formal pledge for not sharing any sensitive nuclear technology or material and maintaining its voluntary suspension on testing nuclear weapons, the NSG-participating governments granted India a 'clean waiver' and made the country eligible to receive advanced nuclear technologies to enrich uranium and reprocess plutonium.
- However, the non-membership of the NSG Group has made the country devoid of the latest nuclear technologies. In 2016, India applied for NSG membership.
- The majority of the 48-member NSG group supported India's stand for NSG membership, but China along with New Zealand, Ireland, Turkey, South Africa and Austria were opposed to India's admittance into the NSG group. China insisted the signing of the NPT Treaty by India in order to get NSG membership and further, wants to have a non-discriminatory criterion for states' admission into the NSG Group. Basically, China's resistance clearly indicates its stand of supporting Pakistan's entry into the NSG group.

5.3.2.1 India's Benefits of NSG Membership

In 2016, India applied for NSG membership, but due to resistance from China, India has not been admitted into the NSG member group. NSG membership will extend the following benefits:

- NSG membership will basically increase the country's access to nuclear materials such as uranium and plutonium reserves in the field of nuclear energy from the members' country. Namibia is the fourth largest producer of uranium who had agreed to sell the nuclear fuel to India in the year 2009. However, the same could not materialise, as Namibia has signed the Pelindaba Treaty, which is an African version of the NPT Treaty, thereby, controlling the uranium supply from the African continent to the rest of the world. If India will get the membership of the NSG, such

KEY POINTS

- **Brought in 1974**–in response to the Indian nuclear test (Smiling Buddha).
- It is a **multilateral export control regime.**
- It is a **group of nuclear supplier countries that seek to prevent nuclear proliferation** by controlling the export of materials, equipment and technology that can be used to manufacture nuclear weapons.
- The NSG first met in November 1975 in London, and is thus, popularly referred to as the '**London Club**'.
- It is **not a formal organisation, and its guidelines are not binding.** Decisions, including membership, are made by consensus.
- **Membership:** 48 supplier states.

Criteria for Membership

- Ability to supply items (including items in transit) covered by the annexes to parts 1 and 2 of the NSG Guidelines;
- Adherence to the Guidelines and action in accordance with them;
- Enforcement of a legally based domestic export control system which gives effect to the commitment to act in accordance with the Guidelines;
- Full compliance with the obligations of one or more of nuclear non-proliferation agreement.
- Support of international efforts towards non-proliferation of weapons of mass destruction and of their delivery vehicle.

Why the membership is important for India?

- Membership will **increase India's access to state-of-the-art technology from the other members of the Group.**
- Access to technology and being allowed to produce nuclear equipment will give a boost to the **Make in India programme.** That will, in turn, boost the economic growth of our country.
- As per India's INDC under the Paris Climate Agreement, commitment to reducing dependence on fossil fuels and ensuring that 40% of its energy is sourced from renewable and clean sources. In order to achieve this target, we need to scale up nuclear power production. This can only happen if India gains access to the NSG.
- India will get **an opportunity to voice its concern if in case of change in the provision of the NSG guidelines. Other benefits associated with NSG membership, once admitted, include the following:**
- Timely information on nuclear matters.
- Contributes by way of information.
- Has confirmed credentials.
- Can act as an instrument of harmonisation and coordination.
- Is part of a very transparent process.

reservations from Namibia will automatically get diluted.

- India's membership to the NSG Group will provide access and enable it to receive new and latest nuclear technologies for enriching uranium or plutonium processing from other member countries and further increase the production of nuclear power in India.
- India's membership to the NSG Group will provide access to new and latest technology and further exchange of technology in the field of nuclear energy which will further boost the 'Make in India' programme, as announced by Prime Minister, Narendra Modi, and in turn, enhance the country's economic growth, thereby, producing more jobs in the country. India can also commercially sell its nuclear power equipment to other countries and also provide training to various unemployed youth in the National Skill Development Programme through the creation of various skill courses in the field of nuclear power.
- According to India's INDC (Intended Nationally Determine Contribution), under the Paris Climate Agreement, the country is committed to reduce its dependence on fossil fuels and further ensure that 40% of the country's energy demand is sourced from renewable and clean sources and in order to achieve this, the nuclear power production has to be enhanced. This will only be possible if India gets the membership of the NSG.

5.3.3 The Wassenaar Arrangement

The Wassenaar Arrangement consists of an elite group of countries, which is a Multilateral Export Control Regime (MECR), subscribing to arms export control, similar on the line of the NSG and MTCR. The agreement is based on Export Controls for conventional arms and dual-use goods and technologies consisting of 42 participating countries including all the permanent members of UN Security Council except China and consisting of many former Comecon (Warsaw Pact) countries. **The agreement was set up in order to contribute towards regional and international security and stability in transfers of conventional arms and dual-use goods and technologies through the promotion of transparency and greater accountability.**

It was formed on 12 July 1996 in Wassenaar, near to the Hague in the Netherlands and is the descendant to the Cold War Era Coordinating Committee for Multilateral Export Controls (COCOM). The Wassenaar Arrangement primarily focused on the lucidity of national export control regimes and is considered less strict than COCOM. Its administrative Secretariat is located in Vienna, Austria. Akin to COCOM, however, it is not a treaty, and therefore, is not legally binding. **As per the existing procedure, every six months, member countries exchange information on conventional arms deliveries to non-Wassenaar members, thereby, falling under eight categories such as battle tanks, Armoured Fighting Vehicles (AFVs), large-caliber artillery, military aircraft, military helicopters, warships, missiles or missile systems and small arms and light weapons.**

5.3.3.1 India as a Member of the Wassenaar Agreement

India has been admitted as a 42nd member of the Wassenaar Agreement in December 2017. This will further polish the country's non-proliferation credentials, despite not being party to the NPT and will further broaden its access to sensitive technologies, so as to cater to the demands of the space and defence sector. **Since the signing of the US-India Civil Nuclear Deal in 2005, India was constantly trying to acquire membership of the NSG, MTCR, Austrian Group and Wassenaar Agreement.** Resultantly, with the backing of the United States, India got the membership of the MTCR in 2016 and thereafter, was admitted as a member of the Wassenaar Agreement in the year 2017. The WA membership will form a strong case for India's membership to the NSG as India's efforts at the NSG were blocked by China with India, not being a member to the WA agreement. **Now with the WA membership, India will be able to get easier access of dual use technologies and military equipment and its licensing which are basically banned for non-participating members. The country will also be able to sell its nuclear reactors and other equipment and materials without attracting any adverse reaction and will be in a better position to collaborate with other countries in the development of such capabilities.**

WARSAW PACT

The Warsaw Pact, formally recognised as the Treaty of Friendship, Cooperation and Mutual Assistance, from 14 May 1955 to 1 July 1991 was a collective defence treaty, signed in Warsaw, Poland, among the Soviet Union and seven Soviet satellite states of Central and Eastern Europe such as Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland and Romania during the Cold War. The treaty provided for a united military command and for the maintenance of Soviet military units on the territories of the other participating states. The Warsaw Pact was the military complement to the Council for Mutual Economic Assistance (CoMEcon) and was established in order to counter NATO.

5.3.4 The Australia Group

It is a Multilateral Export Control Regime (MECR) and an informal countries group, set up in 1985, which seeks to identify the exports that do not contribute to the development and spread of chemical or biological weapons. Initially, the group consisted of 15 members, which hosted its first meeting in Brussels, Belgium, in September 1989. With the inclusion of India on 19 January 2018, it has currently 43 members (42 members and the EU). Countries such as China, Pakistan, North Korea and Iran are not members. It is named after the Australian initiative to form the group and its secretariat is also managed by Australia. **There is no legally binding obligation on the member countries of the Australia Group. Primarily, the group was focused on chemical agents, but by 1990, the mandate was expanded to include biological agents.** In order to discuss the enhanced way of effectiveness of participating nations for preventing would be proliferators for getting CBW materials and its use, the group meets every year. The nation's parties to the Australia Group are also parties to the Chemical Weapons Convention and the Biological Weapons Convention.

5.3.4.1 India and Australia Group

India was admitted as the 43rd member of the group on 19 January 2018. The joining of India in the Australian Group will give a big boost to getting membership of the NSG Group. This will also help to raise the country's status in the field of NPT, despite being non-signatory to the Treaty and further will help in acquiring the latest and critical technologies. **The country is the first among the South Asian countries to acquire the membership of the Group.** Ever since India signed a nuclear deal with the United States in 2008, it has been trying to acquire the membership of MECRs such as the Wassenaar Agreement, the MTCR and the Australian Group. **India was inducted as a 42nd member of the Wassenaar Agreement in December 2017 and also acquired the membership of the MTCR in June 2016.** Now to restrict China, which is curbing India's entry to the NSG Group, India's joining of the Australia Group will give the upper hand to India in becoming a member of the NSG Group.

5.3.5 Missile Technology Control Regime (MTCR)

The Missile Technology Control Regime (MTCR) is a multilateral and voluntary partnership for the non-proliferation of missiles, capable of carrying chemical, biological and nuclear weapons of mass destruction and unmanned aerial vehicle technology, capable of carrying above 500 kilograms payload for more than 300 kilometres among 35 countries. It was established in April 1987 by the G7 countries, such as Canada, France, Germany, Italy, Japan, the United Kingdom and the United States, being a non-legally binding treaty. The MTCR controls the technologies and materials exports, which are involved in ballistic missile systems and unmanned aerial vehicles, particularly capable of carrying nuclear warheads of above 500 kilograms payload for more than 300 kilometres. The MTCR regime is a non-treaty member countries association, having certain guidelines, regarding the sharing of information, control laws and missile systems export policies and a regulation mechanism, so as to curb the transfer of technologies. Now, 35 full members, including India, are the members of the MTCR and four 'non-adherent members' – Israel, Macedonia, Romania and Slovakia, excluding China, which is not a member of this regime. These efforts are being strengthened by 'The International Code of Conduct against Ballistic Missile Proliferation', also known as the Hague Code of Conduct (HCOC), which was set up on 25 November 2002, as an arrangement to prevent the proliferation of ballistic missiles with 136 UN member countries, including India. Under this regime, the members must

have national policies, which should govern the export of ballistic missiles, cruise missiles, unmanned aerial vehicles, space launch vehicles, drones, remotely piloted vehicles, sounding rockets and their components.

5.3.5.1 India as a Member of the MTCR

India was admitted as a full member of the MTCR in June, 2016, with the consensus of other nations and also agreed to join the HCOC which will further strengthen its case for the membership of other MECRs such as the NSG. With this membership, there will be a boost to the defence sector and further enable India to purchase high-end missile technology and further facilitate India in the running of joint programmes for the development of unmanned aerial vehicles with other countries. Also, India will be able to sell its missiles easily to other non-member countries, such as selling of BrahMos to Vietnam, making India a significant arm exporter for the first time. With an entry in the MTCR, the probability of India with its joint venture with Russia and the United States for exporting of UAVs, such as Reaper and Global Hawk and Israel missile defence interceptor, such as Arrow II have enhanced. The ISRO will also get access to the forbidden cryogenic technology from Russia for use in space exploration operations with MTCR membership. MTCR membership can be used to put pressure on China for not being a member of the MTCR and clearing the way for India's membership for the NSG.

5.3.6 Comprehensive Nuclear-Test-Ban Treaty

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is the **treaty banning all nuclear explosions – everywhere, by everyone.** The Treaty was negotiated at the Conference on Disarmament in Geneva and adopted by the United Nations General Assembly. **It opened for signature on 24 September 1996. Although more than 180 countries have signed the CTBT, and mostly ratified it, the treaty can only enter into force, after it is ratified by eight countries with nuclear technology capacity, namely China, Egypt, India, Iran, Israel, North Korea, Pakistan and the United States.**

- The CTBT is the last barrier on the way to develop nuclear weapons. It curbs the development of new nuclear weapons and the improvement of existing nuclear weapon designs.
- **When the Treaty enters into force, it provides a legally binding norm against nuclear testing.** The Treaty also helps to prevent human suffering and environmental damages caused by nuclear testing.

The UN Chief Antonio Guterres reiterated his appeal to eight nations, including India and the United States, to **ratify the CTBT,** saying the failure to bring it into force undermines global efforts to ensure a world free of atomic weapons.

5.4 INDIA'S NFU POLICY

It refers to a pledge or a policy by a nuclear power, **not to use nuclear weapons as a means of warfare unless first attacked by an adversary using nuclear weapons.** Earlier, the concept had also been applied to chemical and biological warfare.

India first adopted a 'No first use' policy after its second nuclear tests, Pokhran-II, in 1998. In August 1999, the Indian government released a draft of the doctrine which asserts that nuclear weapons are solely for deterrence and that **India will pursue a policy of 'retaliation only'.**

The document also maintains that India 'will not be the first to initiate a nuclear first strike but will respond with punitive retaliation should deterrence fail' and that decisions to authorise the use of nuclear weapons would be made by the Prime Minister or his 'designated successor(s)'.

Note: The Defence Minister of India has given major hints about a possible review of the policy of 'no first use' of nuclear weapons and said it will depend on circumstances in future.

5.4.1 Why India Should Retain This Policy?

- Adopting a 'no first use' policy **enables New Delhi to keep the nuclear threshold high,** especially as Pakistan tries to lower the threshold by developing tactical nuclear weapons, the Hatf-9 with 60 km range.
- It must also be noted that New Delhi is not bordered by just one nuclear weapon state. China adopts a 'no first use' policy and in spite of calls for Beijing to revise its 'no first use' doctrine, it is unlikely to do so. Hence, **if New Delhi gave up its 'no first use' doctrine, it could give Beijing a chance to adopt a first-strike policy and shift blame on India.**

- In fact, India's adoption of a first-strike policy would be an **easy excuse for Beijing to give up its 'no first use' doctrine against the United States and Russia as well.**
- Moreover, India has always promoted herself as a responsible nuclear weapon state. Hence, **a first-strike policy would severely damage India's reputation as a responsible nuclear weapon state.**
- Also, it is India's 'no first use' doctrine that has enabled both Pakistan and India to keep their nuclear arsenal in a de-mated posture rather than a ready deterrent posture. This means nuclear warheads are not mated with the delivery systems. **This reduces the chances of nuclear terrorism in Pakistan and also reduces the likelihood of an accidental launch of a nuclear weapon.** A first-strike policy by India may not have allowed Pakistan to keep their nuclear arsenal in a de-mated posture.
- **A first-strike policy, coupled with a ballistic missile defence system, could provoke Pakistan to launch a nuclear pre-emptive strike** against India.
- By adopting a 'no first use' doctrine, New Delhi has also made it evident that nuclear weapons are indeed the weapons of last resort. **Abandoning this doctrine would make it evident that India considers the option of using nuclear weapons in the initial phases of the conflict.**

5.5 NUCLEAR DEALS OF INDIA AND NUCLEAR DIPLOMACY

Because of non-participation in the global forums and treaties like the Nuclear Suppliers Group, Comprehensive Test Ban Treaty (CTBT), the Nuclear NPT, etc., India was not a part of the nuclear commerce of the world, for a long time.

On signing the 123 agreement, also known as Indo-US civil nuclear deal, in 2008, a major breakthrough was achieved in this sector. Under the deal, it was agreed by India to isolate its civil nuclear facilities from the military nuclear facilities and thus keep all its civil nuclear facilities under the IAEA, that is, IAEA safeguards. In exchange for this, full civil nuclear cooperation with India was decided to be worked about from the end of the United States. However, the execution of this deal took more than three years. Numerous complex stages, like the revision of the US domestic law, as in the Atomic Energy Act of 1954, especially the civil-military nuclear Separation Plan in India, the India-IAEA safeguards (inspections) Agreement, as well as the allowance for an exemption for India by the NSG, the export-control cartel, that was formed chiefly in response to the first nuclear test conducted by India in 1974, were the major developments under the regime of this deal.

5.5.1 Nuclear Energy Agreements Signed between India and Different Countries

- **France** became the first country to sign a civilian nuclear agreement with India on 30 September 2008, which happened only after the complete waiver was provided by the NSG. Nicolas Sarkozy, the French President, during his visit to India in December 2010, signed the General Framework Agreement and the early Works Agreement between NPCIL and M/s AREVA for the implementation of EPR (Extended Producer Responsibility) for the Jaitapur Nuclear Power Project (JNPP). Following the M/s AREVA's restructuring, French utility EDF was designated as the lead agency for negotiations and implementations of the JNPP so on 22 March 2016, EDF and NPCIL signed a revised MoU for the construction of six EPR units at Jaitapur of 1650 megawatts each.
- India has been assisted well by **Russia** to plan a nuclear plant for its nuclear submarine. Under a new treaty signed, it was accepted to provide India the full freedom to progress with the closed fuel cycle, including mining, fuel preparation for reactors and reprocessing of spent fuel. An agreement was signed between India and Russia, in 2010. As per this agreement, India will acquire 12 nuclear reactors from Russia that will include one to be commissioned in Kudankulam (KKNPP) (where a Russian reactor is already in operation) and for the rest, the site is yet to be decided. KNPP units 1 and 2 have already become operational and the construction of units 3 and 4 and 5 and 6 is going on.
- **India and Mongolia** signed the crucial civil nuclear agreement on 15 June 2009 regarding the supply of uranium to India.

- **India** signed a civil nuclear energy agreement with **Namibia** on 2 September 2009, permitting the supply of uranium from the African country.
- A civil nuclear agreement was signed between **India and Argentina**, enabling cooperation and strategic partnership. Both the countries have decided to encourage and upkeep scientific, technical and profitable collaboration for a mutual benefit in this field.
- **India and Canada** also signed a civil nuclear co-operation agreement on 28 June 2010 offering access to the growing nuclear market of India and also to fuel its reactors. They accord as the only users of heavy water nuclear technology.
- An agreement was contracted between **India and Kazakhstan** for support in peaceful uses of atomic energy. This contract visualises a legal structure to supply fuel, construct and operate atomic power plants. Besides these, exploration and joint mining of uranium, the give-and-take system of scientific and research materials, as well as reactor safety mechanisms and the use of radiation expertise for healthcare were included as other visions of the contract.
- **India and South Korea** also engaged into a nuclear agreement on 25 July 2011 enabling South Korea's participation in the nuclear expansion plan of India and to bid for erecting the nuclear power plants in India.
- **India-US** nuclear collaboration is also called as 123 Agreement.
- In 2014, a civil-nuclear agreement was signed between **India and Australia,** permitting the export of uranium to India. Australia stands as the world's third largest uranium manufacturer and hence, the agreement enables the supply of uranium for peaceful power generation for public usage in India.
- A nuclear deal was signed in 2015, between **India and Japan,** though there were apprehensions for Japan regarding the liability clause and the tracking clause, the two countries in November, 2016 signed a civil-nuclear deal over the peaceful uses of nuclear energy and with this India is the first non-NPT country to sign a nuclear deal with Japan. This landmark deal came into force in July 2017, which would enable Japan in exporting of nuclear power plant technology, as well as providing finance for the management of nuclear power plants in India. Through this deal, Japan will assist India in the management of nuclear waste and further undertake of joint manufacture of components of the nuclear plant under the Make-in-India programme.
- **India and Vietnam** signed a civil nuclear deal in December 2016 for the peaceful uses of nuclear energy and further strengthening the technical cooperation in nuclear energy. Vietnam is the fourteenth country with which India has signed a nuclear deal on the research areas of nuclear reactors. The Memorandum of Understanding asks for the cooperation between the DAE's Global Centre for Nuclear Energy Partnership (GCNEP) and the Vietnam Atomic Energy Institute (VinAtom).
- India signed a trilateral agreement in March 2018 with **Russia and Bangladesh** for the cooperation in the civil nuclear field. This will allow Indian companies in the construction and installation of nuclear power project on foreign soil. The parties will cooperate in the field of personnel training, consultation and material and equipment supply in non-critical category for undertaking the construction of Roppur nuclear power plant project in Bangladesh.

5.6 NUCLEAR LIABILITY ACT, 2010

Nuclear Liability Act 2010 is also known by another name as the **Civil Liability for Nuclear Damage Act 2010.**

AIM: To provide a civil liability for instances of nuclear damage and prompt compensation to the victims of the nuclear incident through a NO FAULT LIABILITY to the operator. The appointment of the claims commissioner and the establishment of nuclear damage claims commission.

NO FAULT LIABILITY implies 'absolute legal responsibility for an inquiry that can be imposed on the wrong doer without proof of carelessness or fault'.

This Act was one of the must steps, required to activate the 2008 Indo-US civilian nuclear agreement. Though, India is not a party to NPT; however, it is still allowed to carry nuclear commerce with the rest of the world. India becomes a member of the International

Convention on Liability in the civil nuclear arena after passing this Act.

1. The maximum amount of liability is capped to ₹500 crore, to be paid by the operator of the Nuclear Plant, by the Act.
2. In case of the cost of damages exceeding this amount, the central government will pay up to ₹300 million.

5.6.1 Necessity of this Act

The amount of electricity produced by the nuclear power plant is planned to be increased to 14,000 megawatts by 2020 and to 27,500 megawatts by 2032 and up to 25% of electricity will be generated by nuclear power plants by 2050, as per India's plans.

It also serves to bind operators and governments legally and financially that can provide relief, if any unwanted accident happens.

5.6.2 Criticism

- The Nuclear Power Corporation of India Limited, which functions as the operator, is a government-owned body. Hence, in case of any nuclear damage, the entire compensation has to be borne by the Government for the operator's side too.
- **Clause 17(a) and (b):** Only the operator can sue the manufacturers and suppliers and not the victims. Also, the recourse taken by the operator is only ₹1500 Crore.
- Too short time limit to make claim (within 10 years), which may not be sufficient, if there is any long-term damage.
- **Clause 35:** In the case of a nuclear accident, the operator or responsible persons will undergo the trial under the Nuclear Damage Claims Commission and besides that, no court is given the authority. This may divide the country into zones with each zone having a claims commissioner.
- On the contrary, the US counterpart, the Prime Anderson Act, enables lawsuit and criminal proceedings proceed under US court.
- **Clause 46:** The suppliers are exposed to domestic court law, under which citizens can drag them to court for settlement of Compensation. Clause 45 provides discretionary power to wave liability.

The United States has issues with the clauses 17(b) and 46 since they could enable to seek compensation from the supplier. This leads to the feeling that this is a big burden on them and that this could ultimately lead to unlimited liability on the suppliers.

5.6.3 Suggestions and Way Forward

1. A Nuclear Insurance Pool needs to be established for the country through a Nuclear Liability Fund by operationalizing the normal surcharge of say 5 paise per unit of nuclear power that is produced. Even at this rate, at current production level, about ₹200 crore annually could be provided.
2. With a view to move ahead with the strategic development, the legacy of mistrust needs to be removed. The first thing is ratification of the convention on supplementary compensation, which was signed by India in 2010, post ratification; the Indian government will be strengthened to stand on the interpretation. This will enable the NPCIL to open preliminary techno-economic discussion with the US suppliers, while offering similar kind of assurances to other foreign suppliers.

5.7 PHASING OUT OF NUCLEAR POWER IN EUROPE

A nuclear power phase-out refers to the termination of usage of the nuclear power for energy production. It is often introduced due to concerns about nuclear power, it usually includes shutting down nuclear power plants and thereby, taking a step towards renewable energy and fossil fuels.

Three nuclear accidents have influenced the discontinuation of nuclear power, namely **the 1979 Three Mile Island partial nuclear meltdown, which happened in the United States; the 1986 Chernobyl disaster in the USSR; and the 2011 Fukushima nuclear disaster that happened in Japan.**

Sweden (1980) accords to be the first country to begin a phase-out, which, in 2009, was repealed. It was followed by Italy (in 1987), Belgium (in 1999) and Germany (in 2000). Austria and Spain have also enacted laws to cease the construction of new nuclear power

stations. Many other European countries have debated phase-outs.

Following the March 2011 Fukushima nuclear disaster, eight of its 17 reactors were permanently shut down by Germany and it pledged to close the rest by the end of 2022. In late 2021, all but three of the remaining German nuclear power plants were shut down. **In October 2022, the Chancellor decided that Germany's three remaining nuclear power reactors would keep operating until mid-April 2023 to offset reduced gas supply from Russia.**

Italy too voted overwhelmingly to keep their country non-nuclear. Moreover, the construction of new reactors has been banned by Switzerland and Spain.

As of June 2023, there were 209 nuclear reactors permanently shut down worldwide. The United States recorded the largest number of shutdowns, with 41 units followed by the UK with 36 reactors; the least being Pakistan with just one reactor. Shutdowns refer to a subcritical reactor state as defined by technical specifications and also require other factors like the reactor control key being secured.

5.8 NEW START TREATY

The **New START Treaty** was in between the United States and the Russian Federation for further reduction and limitation of strategic offensive arms.

This treaty has verification measures at on-site inspections and exhibitions, to monitor nuclear arms. Under this treaty, there is a provision to exchange all arms exchange data to each and other nation.

New START Treaty duration is for ten years, unless superseded by a subsequent agreement. After the termination of the 2002 Moscow Treaty, New START Treaty entered into force. This treaty will not restrict the testing, development or deployment of current or planned missile defence programmes of the United States.

MT to MW (MegaTonne to MegaWatt): In this provision, Russia will provide atom bomb based highly enriched uranium (in tonne weight) to the United States, which the United States will utilise for electricity generation (in unit of watt).

NEW START DEAL

- Signed on 8 April 2010 in Prague, and, after ratification entered into force on 5 February 2011.
- Replaced the Treaty of Moscow (SORT), which was to expire in December 2012.
- The New START treaty is a successor to the START I treaty, which expired in December 2009. The proposed START II treaty was signed but never entered into force, and the START III treaty negotiations were never concluded.

Impact of the New START Treaty

- Number of strategic nuclear missile launchers reduced by half.
- Replacement of SORT mechanism by a new inspection and verification regime.
- The number of deployed strategic nuclear warheads limited to 1,550 which is down nearly two-third from START I treaty.
- Number of deployed and non-deployed InterContinental Ballistic Missile (ICBM) launchers, Submarine Launched Ballistic Missile (SLBM) launchers and heavy bombers equipped for nuclear armaments limited to 800.

5.9 NUCLEAR SECURITY SUMMIT

To warn the world against nuclear terrorism, Obama hosted the first Nuclear Security Summit (NSS) in Washington in 2010. The main aim of this summit was to draw attention towards the use of secure nuclear material so we can prevent nuclear terrorism worldwide. **This summit is conducted on a periodical basis after every two years.** There were four summits in total – in Washington, D.C. in 2010, Seoul, South Korea in 2012, the Hague, Netherlands in 2014 and Washington, D.C. again in 2016.

5.10 INTERNATIONAL PANEL ON FISSILE MATERIAL

The International Panel on Fissile Material (IPFM) was established in 2006, as a group of 18 countries, which are independent nuclear experts with an objective to secure and sharply reduce stocks of highly enriched uranium and also separated plutonium. **Due to these initiatives, key materials of nuclear weapons will be protected and limit its further production.** (List of IPFM countries – Brazil, Canada, China, France, Germany, India, Iran, Japan, Netherland, Mexico,

Norway, Pakistan, South Korea, Russia, Africa, Sweden, the United States and the United Kingdom).

5.11 WORLD'S MAJOR NUCLEAR DISASTERS (AT LEVEL 7, 6 AND 5)

1. **Chernobyl, Ukraine, 1986 – Level 7:** It has been thought to be the worst nuclear accident in history, being one of the only two that are classified as the Level 7 event on the International Nuclear Event Scale (the other is the Fukushima Daiichi disaster in 2011). The official Soviet fatality count of 31 deaths has been dubious. Not only this, long-term effects like cancers and deformities are still being accounted for.
2. **Fukushima, Japan, 2011 – Level 7:** The Fukushima Daiichi nuclear disaster (the largest nuclear tragedy since the Chernobyl disaster of 1986) represents a series of catastrophes (Tohoku Tsunami) resulting in equipment failures, nuclear meltdowns and release of radioactive materials at the Fukushima Nuclear Power Plant, that took place on 11 March 2011. It is also accorded as the second disaster (along with Chernobyl) to size a Level 7 on the INES (International Nuclear and Radiological Event Scale).
3. **Kyshtym, Russia, 1957 – Level 6:** On 29 September 1957, a radiation pollution incident occurred at Mayak (a nuclear fuel reprocessing plant in the Soviet Union) and is known as the Kyshtymnuclear disaster.
4. **Windscale Fire (Sellafield), UK, 1957 – Level 5:** The worst nuclear disaster in the history of the Great Britain was Windscale Fire (Sellafield) and is measured as a level 5 on the INES scale.
5. **Three Mile Island Accident, Pennsylvania USA, 1979 – Level 5:** On 28 March, two nuclear reactor failures occurred, and hence, it was recorded as the worst disaster in commercial nuclear power plant history. Due to this disaster, radioactive gases and radioactive iodine were released into the environment. Fortunately, not a single type of cancer has been linked with the accident as per the studies that have been conducted.
6. **Goiania Accident, Brazil, 1987 – Level 5:** A radioactive contamination accident harmed the Brazilian state of Goais on 13 September 1987. An old radiotherapy source was stolen from an abandoned hospital site in the city. Subsequently, many people carried and mishandled it, which ultimately cost four lives. Besides this adverse effect of the accident, 112,000 people were examined for radioactive contaminations with 249 having significant levels of radioactive material in or on their body.